Agriculture Canada

Handling Agricultural Materials

Screw and bucket conveyors

Canada

Handling Agricultural Materials

Screw and bucket conveyors

Research Branch
Agriculture Canada

Publication 1834/E
1989

Cat. No. A15-1834/1989E
ISBN 0-660-13090-4
Printed 1989

Available in Canada through
authorized bookstore agents and
other bookstores or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

Price is subject to change without notice

Previously published under the title
Canadian Agricultural Materials Handling Manual.
2.3 Screw and Bucket Conveyors.
Agric. Can. Publ. 5002

Also available in French under the title
Manutention des produits agricoles : Transporteurs à vis
et élévateurs à godets.

Canadian Cataloguing in Publication Data
Handling agricultural materials : screw and
bucket conveyors

(Publication ; 1834)

Previously published as: Canadian agricultural
materials handling manual. 2.3. Screw and bucket
conveyors.
Issued also in French.
Prepared by UMA Engineering Ltd. cf. Forward.
Bibliography: p.
Cat. no. A15-1834/1989E
ISBN 0-660-13090-4

1. Screw conveyors. 2. Conveying machinery.
3. Farm equipment. I. Rudnitski, Sharon.
II. Birenbaum, Rhonda. III. Canada. Agriculture
Canada. Research Branch. IV. UMA Engineering Ltd.
V. Series: Publication (Canada. Agriculture Canada).
English ; 1834.

TJ1390H36 1989 621.8'67 C89-099202-9

Staff editor
Sharon Rudnitski
Research Program Service

Contract editor
Rhonda Birenbaum

Scientific adviser for contract research
L. Heslop
Engineering and Statistical Research Centre

CONTENTS

Foreword 5

1 **SCREW CONVEYORS** 7

1.1 **Screw feeders** 7
1.2 **Trough ends and hangers** 7
1.3 **Types of conveyor screws** 8
1.4 Helicoid-flight conveyor screws 8
1.5 Sectional-flight conveyor screws 8
1.6 Short-pitch conveyor screws 8
1.7 Tapering-flight conveyor screws 8
1.8 Stepped-diameter conveyor screws 8
1.9 Stepped-pitch conveyor screws 8
1.10 Long-pitch conveyor screws 9
1.11 Double-flight conveyor screws 9
1.12 Double-flight, short-pitch conveyor screws 9
1.13 Ribbon-flight conveyor screws 9
1.14 Abrasion-resistant conveyor screws 9
1.15 Corrosion-resistant conveyor screws 9
1.16 **Drive shafts, end shafts, and couplings** 9
1.17 **Trough end plates** 10
1.18 Drive shaft trough ends 10
1.19 Countershaft trough ends 10
1.20 Enclosed countershaft trough ends 11
1.21 **Trough sections** 12
1.22 Seal glands and trough end seals 12
1.23 **Troughs** 12
1.24 Flanged troughs 12
1.25 Angle-flanged troughs 12
1.26 Dust seal troughs and covers 12
1.27 Flared troughs 12
1.28 Drop-bottom troughs 12
1.29 Jacketed troughs 12
1.30 Rectangular troughs 13
1.31 Channel-section troughs 14
1.32 **Shrouds** 14
1.33 **Trough discharge spouts and gates** 14
1.34 Trough spouts 14
1.35 Slide gates 14
1.36 Rack-and-pinion slide gates 15

2 **FARM AUGERS** 15

2.1 **Specialty conveyors** 15

3 **SELECTING CONVEYOR CAPACITY AND SPEED** 15

3.1 **Screw conveyor speed** 18
3.2 Conveyor pitch factor 18
3.3 Loading correction factor 18
3.4 Inclination factor 18
3.5 Equivalent capacity 19
3.6 **Material lump size** 19
3.7 **Sample problem: calculating conveyor speed** 19
3.8 **Power requirements for screw conveyors** 20
3.9 **Sample problem: screw conveyor motor size** 21
3.10 **Screw feeder operating parameters** 21

4 **BUCKET ELEVATORS** 22

4.1 **Power requirements** 24
4.2 **Drive arrangements** 24
4.3 **Operational speed** 24
4.4 **Bucket elevator capacity** 24
4.5 **Sample problem: elevator power** 24
4.6 **Head details** 25
4.7 **Boot details** 25
4.8 **Loading** 27
4.9 **Legging or trunking** 28
4.10 **Head and boot pulleys** 28
4.11 **Belting** 28

5 **GUIDELINES FOR ERECTING CONVEYORS** 28

5.1 **Foundations** 29
5.2 **Lateral support** 29
5.3 **Distributors** 30
5.4 **Belting** 31
5.5 **Buckets** 31
5.6 **Spouting** 31
5.7 Spouting support 32
5.8 **Bucket elevator safety** 32
5.9 **Material damage control** 33

References 35

Tables

1 Agricultural material characteristics 16
2 Horizontal screw conveyor specifications 19
3 Hanger bearing friction factors 20
4 Modified flighting factors 20
5 Screw feeder capacities for agricultural materials 22
6 Screw feeder dimensions 22
7 Screw feeder equivalent lengths based on feeder selection 23
8 Typical spout slopes 32
9 Spout slope and length vs. grain speed 34

Figures

1 Typical screw conveyor 7
2 Portable auger conveyor with feed hopper 7
3 Trough end and hanger locations 8
4 Helicoid flighting 8
5 Sectional flighting 8
6 Flighting types 9
7 Ribbon flighting for sticky materials 9
8 Conveyor shaft coupling 10
9 Split-flight and quick-release couplings 10
10 Conveyor shaft couplings 10
11 Trough ends 11
12 Drive shaft trough ends 12
13 Enclosed countershaft trough ends 12
14 Trough shapes 13
15 U-trough shapes 14
16 Trough spouts 14
17 Slide gate 15
18 Rack-and-pinion slide gates 15
19 Screw feeder components 21
20 Screw feeder with extension conveyor 22
21 Bucket elevator 23
22 Bucket elevator head details 26
23 Bucket elevator boot details 26
24 Inlet positions for gravity-fed bucket elevators 27
25 Inlet positions for force-fed bucket elevators 27
26 Dust takeoff locations for bucket elevators 28
27 Swing-spout distributor 30
28 Rotary-spout distributor 30
29 Standard and self-cleaning dead-ends 33
30 Standard and self-cleaning flow retarders 33

FOREWORD

Handling Agricultural Materials is produced in several parts as a guide to designers of materials-handling systems for farm and associated industries. Sections deal with selection and design of specific types of equipment for materials handling and processing. Items may be required to function independently or as components of a system. The design of a complete system may require information from several sections of the manual.

This section was prepared by UMA Engineering Ltd., Winnipeg, Man., for the Canada Committee on Agricultural Engineering Services of the Canadian Agricultural Services Coordinating Committee.

1 SCREW CONVEYORS

Screw conveyors or augers represent some of the oldest and simplest methods for moving bulk materials. They consist primarily of a conveyor screw rotating in a stationary trough or tube. Rotation of the screw, which is usually supported by hanger bearings, moves material along the length of the trough. Inlets, outlets, gates, and other accessories direct the material and its disposition. Fig. 1 shows a typical screw conveyor.

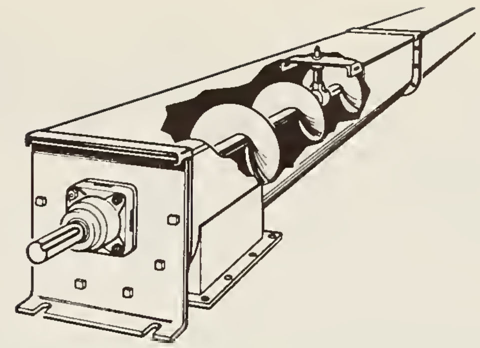


Fig. 1. Typical screw conveyor.
Source: *Screw conveyor engineering catalog no. 7700.*

Compact and easily adapted to congested locations, screw conveyors can be mounted horizontally, vertically, or at any angle. Their supports are simple and easily installed. As well, these conveyors can be effectively sealed to prevent dust or fumes from escaping, or dirt and moisture from entering. Jacketed screw conveyors can serve as dryers or coolers. Or furnished in a wide variety of appropriate materials, they resist corrosion, abrasion, or heat destruction. The portable auger conveyor shown in Fig. 2 can be found on virtually every farming operation in the western world.

1.1 Screw feeders

Screw feeders, modified screw conveyors, control the flow of material from truck hoppers, storage hoppers, bins, or tanks. They operate at constant or variable rates, making them suitable for handling a wide variety of materials: from finely ground flours to more densely processed meals. Also useful as valves, screw feeders can control the flow of material.

Screw feeders are totally enclosed, compact, simple in design, and resistent to dust infiltration. They are also economical to install, operate, and maintain.

1.2 Trough ends and hangers

Trough ends support the conveyor drive and end shafts; hangers support the conveyor couplings. Together these components maintain proper alignment and clearance between the conveyor screw and trough. Fig. 3 shows the locations of the trough ends and hangers on a typical screw conveyor.

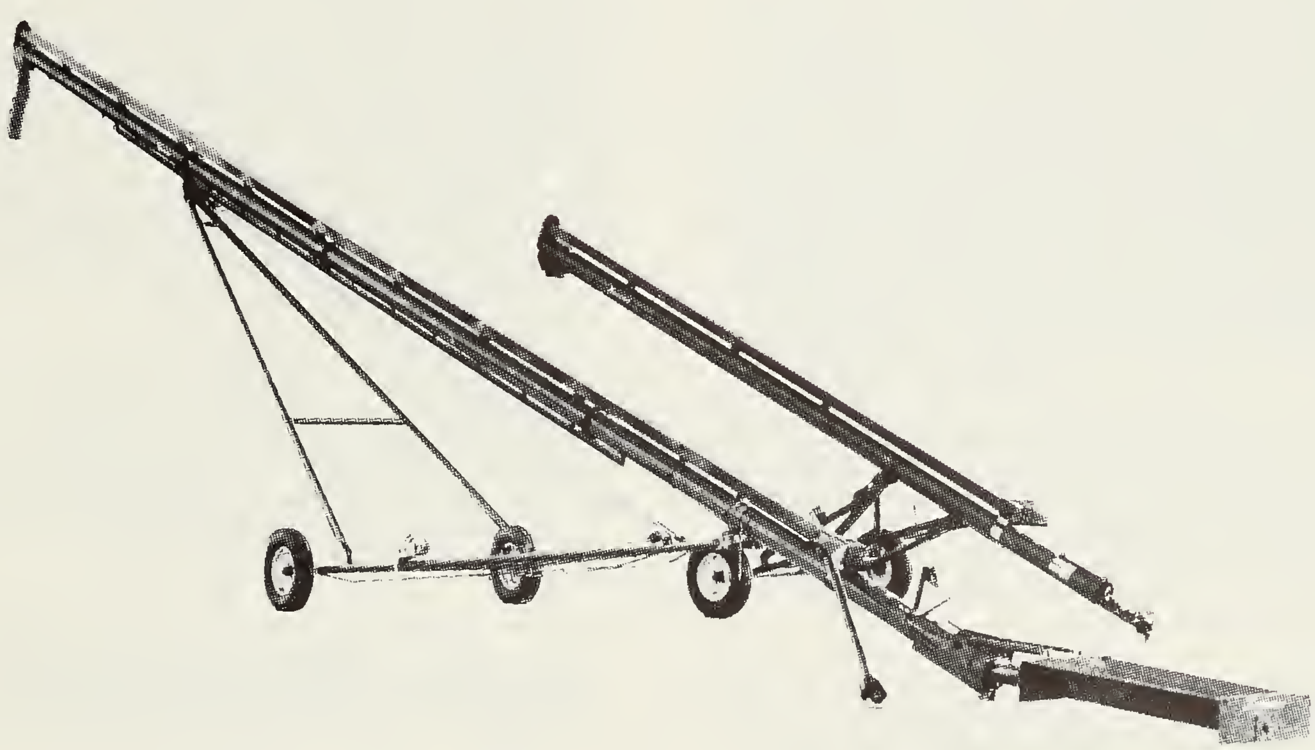


Fig. 2. Portable auger conveyor with feed hopper.

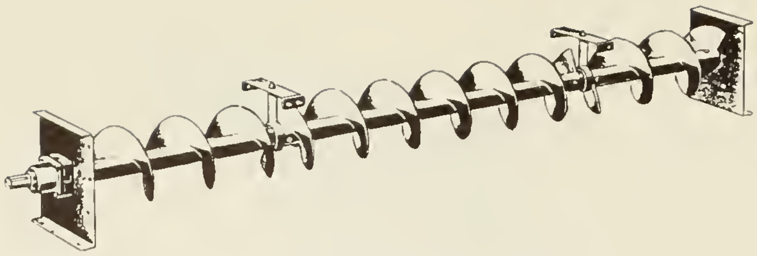


Fig. 3. Trough end and hanger locations.
Source: *Syntron and link-belt material handling equipment.*

Trough end seals are assembled between the flanged blocks and the trough end plates. These seals provide protection from the material being handled for the drive shaft and end shaft bearings.

1.3 Types of conveyor screws

Twelve types of conveyor screws are popular in agricultural applications.

- helicoid-flight
- sectional-flight
- short-pitch
- tapering-flight
- stepped-diameter
- stepped-pitch
- long-pitch
- double-flight
- double-flight, short-pitch
- ribbon-flight
- abrasion-resistant
- corrosion-resistant

1.4 *Helicoid-flight conveyor screws* The helicoid-flight conveyor screw consists of a helix, roll-formed from a flat steel sheet and mounted on a pipe or shaft (Fig. 4). Special rolling equipment forms the helix to the correct diameter, pitch, and thickness, and ensures a smooth, continuous, one-piece flight. The rolling process also hardens and smooths the flight surface.

The one-piece construction gives helicoid-flight conveyor screws superior strength. The absence of laps, rivets, or welds on the carrying face of the flight preserves cleanliness and reduces wear. The smooth surface also reduces friction and power consumption.

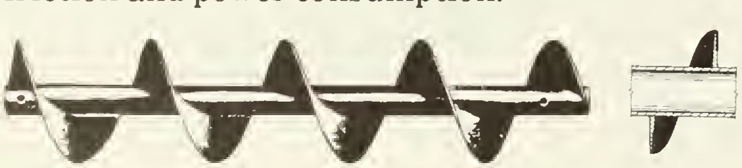


Fig. 4. Helicoid flighting.
Source: *Syntron and link-belt material handling equipment.*

The assembled helicoid-flight conveyor screw is solidly constructed and exceptionally sturdy, and its inherent balance permits operation at high speeds. If the flighting is continuously welded to the centre shaft on one or both sides, the helicoid conveyor screw moves extremely heavy loads.

1.5 *Sectional-flight conveyor screws* Sectional-flight conveyor screws consist of individual flights, each blanked from a flat steel plate and formed into a helix (Fig. 5). The flights are butt-welded together and fastened to the pipe or shaft by intermittent or continuous welds. Formed steel end lugs add strength to the flight attachments. The pitch of sectional flights approximates the diameter.

Sectional flights are available in a variety of diameters, pitches, and thicknesses. They are interchangeable with helicoid-flight conveyor screws of the same diameter and shaft size.

1.6 *Short-pitch conveyor screws* Short-pitch conveyor screws differ from ordinary conveyor screws only in the reduced flight pitch. Use them in conveyors inclined at 20° or more, including vertical conveyors. Used extensively as feeder screws, short-pitch conveyor screws retard flushing, whereby fluid materials flow through the nonoperating conveyor.

1.7 *Tapering-flight conveyor screws* Tapering-flight conveyor screws increase in diameter in the direction of material flow. Use them to move friable, lumpy material from bins or hoppers. Tapering-flight conveyor screws characteristically draw material uniformly along the length of the feed opening.

1.8 *Stepped-diameter conveyor screws* Stepped-diameter conveyor screws consist of regular pitched flights of differing diameters mounted in tandem on a single pipe or shaft. These screws perform nearly as well as tapered-flight screws but are less costly to make. Use them as feeder screws, locating the smaller diameter flights under bins or hoppers to regulate the flow of material.

1.9 *Stepped-pitch conveyor screws* Sectional flights increasing in pitch make up stepped-pitch conveyor screws. Use them as feeder screws to draw fine, free-flowing materials uniformly along the length of the feed opening.

Fig. 5. Sectional flighting.
Source: *Syntron and link-belt material handling equipment.*

1.10 *Long-pitch conveyor screws* An uncommon type of screw, the long-pitch conveyor screw may function as an agitator for liquids or to convey free-flowing materials.

1.11 *Double-flight conveyor screws* These screws consist of two helices attached to a single shaft. They are of regular pitch and promote a smooth, gentle flow and discharge of materials.

1.12 *Double-flight, short-pitch conveyor screws* Use double-flight, short-pitch conveyor screws to accurately regulate feed flowing in screw feeders. They also effectively deter flushing of fluid materials in inoperative conveyors.

Fig. 6 illustrates the previous six screw types.

1.13 *Ribbon-flight conveyor screws* In this type of conveyor screw, welded steel supporting lugs fasten a steel bar rolled to form a continuous helical ribbon flight (Fig. 7).

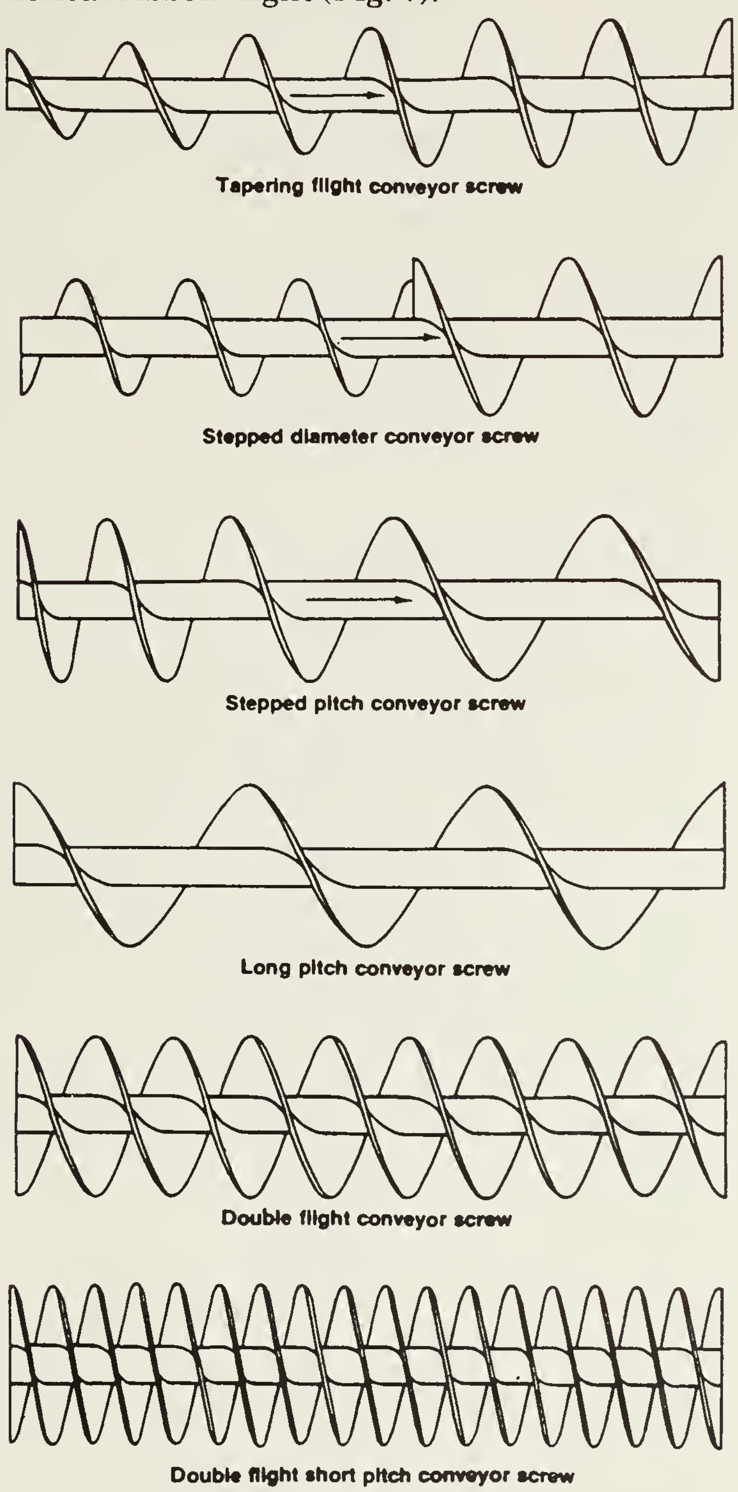


Fig. 6. Flighting types.
Source: ***Syntron and link-belt material handling equipment.***

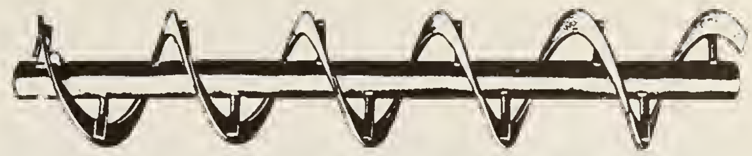


Fig. 7. Ribbon flighting for sticky materials.
Source: ***Syntron and link-belt material handling equipment.***

Use ribbon-flight conveyor screws to transport sticky, gummy, or viscous materials. The open construction of the ribbon flight prevents these materials from adhering to and building up at the point where the flighting connects with the pipe. Ribbon-flight conveyor screws typically handle raw sugar, molasses, asphalt, hot tar, sticky feed mixes, and similar materials.

Where the material moves along the screw all together, the capacity of ribbon screws differs only slightly from that of solid- flight conveyor screws of the same size. Negligible mixing occurs in ribbon screws without supplementary means of agitation.

1.14 *Abrasion-resistant conveyor screws* The particularly severe service encountered when conveying abrasive materials has prompted many attempts to overcome excessive wear on flighting. Several methods have been developed; each offers specific advantages depending on the nature of the material handled and the application.

For agricultural applications, hard surfacing is the most common technique used to protect conveyor screws from abrasion. Hard surfacing involves the application, by arc or torch, of a special compound to the flight periphery or face. It provides an exceptionally hard surface at the points of greatest wear.

1.15 *Corrosion-resistant conveyor screws* Corrosion develops in many different ways so no single material suits all requirements. However, stainless steel, Monel metal, and aluminum conveyor screws best withstand the effects of corrosion encountered in most agricultural settings.

Galvanizing and other similar coating methods protect against mild corrosion. Vulcanized or bonded rubber covering the entire conveyor generally renders the screw resistant to extremely corrosive action.

1.16 Drive shafts, end shafts, and couplings

Design the conveyor drive shaft to provide adequate torque, bending, and shear strength, with closely controlled tolerances for correct bearing clearances.

For very long conveyors or for very heavy loads, use alloy steels, heat-treated high carbon steels, or three-bolt shaft connections.

Conveyor couplings connect and space adjoining sections of the conveyor screw. They also transmit the torque (Fig. 8).

Split-flight and quick-release couplings permit installation or removal of individual conveyor screws without disturbing adjoining sections. The split-flight couplings span two screw sections and can be removed to allow disassembly without disturbing the hangers (Fig. 9). Quick-release couplings are similar; however, they do not span the two sections. Both types of couplings are available for helicoid-flight and sectional-flight screws.

Support the flight portion of the screw conveyor with bearings and hangers located at intermediate positions. Attach them to the trough sides or the trough upper flange. The mounting holes in the hangers are slotted for adjustment and alignment of the bearings. The hangers are available in several configurations. Fig. 10 illustrates various types of hangers.

1.17 Trough end plates

Trough end plates, for either u-shaped or flared troughs, are made of heavy-gauge steel plate. The top is flanged to support the trough cover. End plates are available with or without supporting feet. Fig. 11 shows some examples of trough ends.

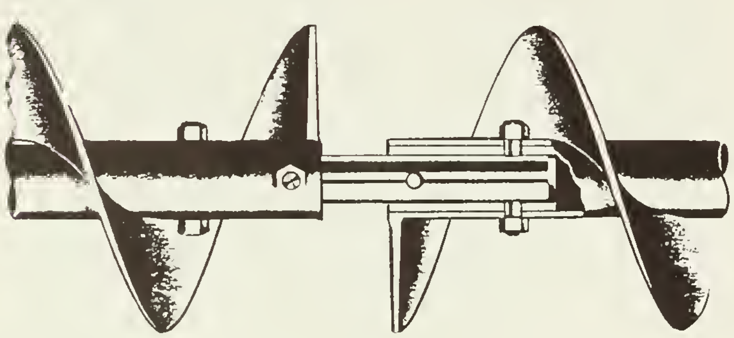


Fig. 8. Conveyor shaft coupling.
Source: ***Syntron and link-belt material handling equipment.***

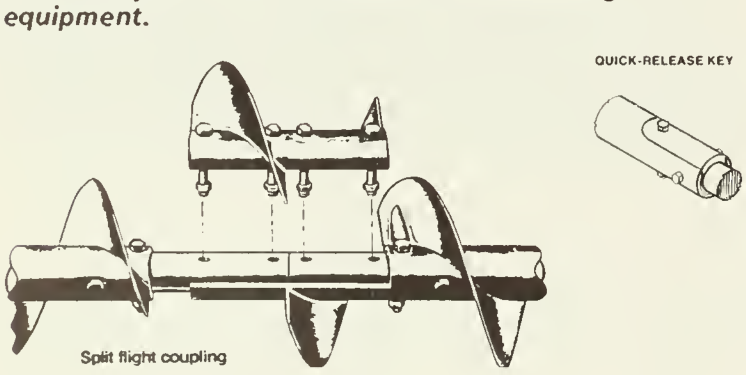


Fig. 9. Split-flight and quick-release couplings.
Source: ***Syntron and link-belt material handling equipment.***

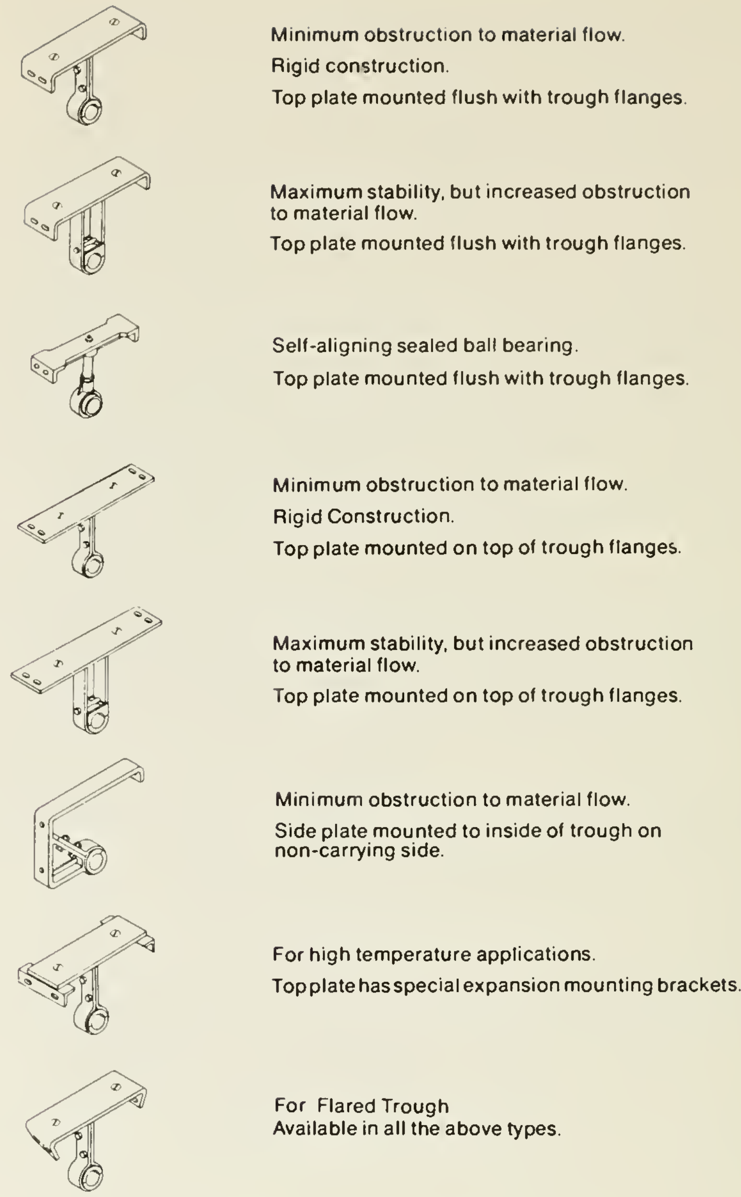


Fig. 10. Conveyor shaft couplings.
Source: ***Screw conveyor engineering catalog no. 7700.***

1.18 *Drive shaft trough ends* Each trough end consists of a rigid shaft operating in a bearing. The ends may be constructed in a double ball bearing or double roller bearing configuration. Design the bearing to accommodate both radial and thrust loads (Fig. 12). A chain drive connected to the power source generally produces the radial, or overhung load. Thrust loads, which operate in either direction, result from the forces required to transport material along the conveyor.

1.19 *Countershaft trough ends* Use countershaft trough ends on screw conveyors where space limitations, interference of adjoining equipment, or better service and maintenance accessibility demand right-angle drives.

Application of countershaft trough ends permits drive installations beside, above, or below the conveyor. It also permits using horizontal drives for inclined conveyors. A common drive for two conveyors intersecting at right angles or for a battery of parallel conveyors driven from a common source can be readily arranged by using countershaft trough ends.

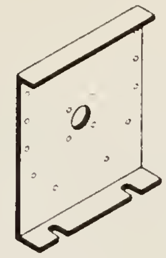
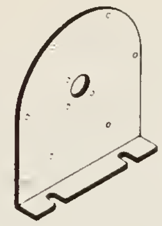
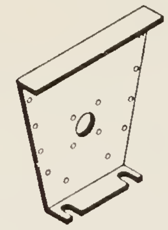
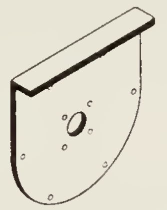
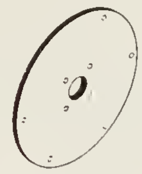
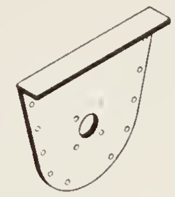
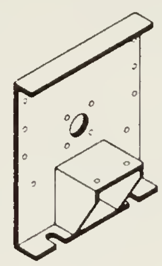
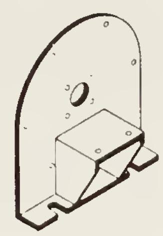
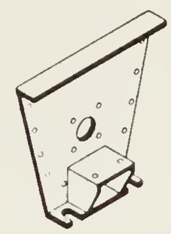
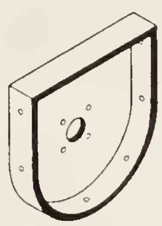
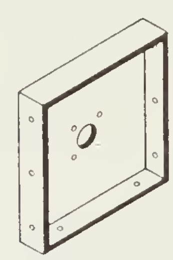
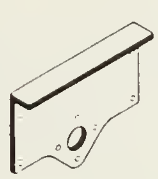
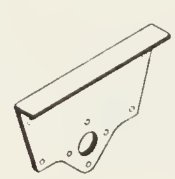
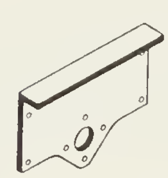
	U-TROUGH	TUBULAR TROUGH	FLARED TROUGH	RECTANGULAR TROUGH	
TROUGH ENDS WITH FEET	 Type CEF	 Type CEFT	 Type CEFV	–	Most commonly used trough end. Bottom flange foot provides support for the conveyor.
TROUGH ENDS WITHOUT FEET	 Type CE	 Type CET	 Type CEV	–	Requires separate flange feet or saddles for support of the conveyor.
OUTBOARD BEARING TROUGH ENDS	 Type CEO	 Type CEOT	 Type CEOV	–	A pedestal is fitted to the trough end plate to support a pillow block. Sufficient space is allowed to mount a seal or flange bearing between the trough end and the pillow block.
INSIDE PATTERN TROUGH ENDS	 Type CEI	–	–	 Type CEW	For inside assembly.
DISCHARGE TROUGH ENDS	 Type CED	–	 Type CEDV	 Type CED	Used to provide discharge directly from the trough end.

Fig. 11. Trough ends.
Source: *Screw conveyor engineering catalog no. 7700.*

1.20 *Enclosed countershaft trough ends* These trough ends provide both durability and built-in safety against bearing failure. Gears operate in a constant oil bath with dirt and grit excluded. This configuration promotes maximum gear life (Fig. 13).

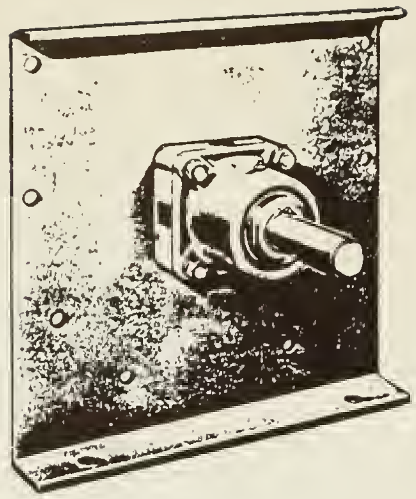


Fig. 12. Drive shaft trough ends.
Source: ***Syntron and link-belt material handling equipment.***

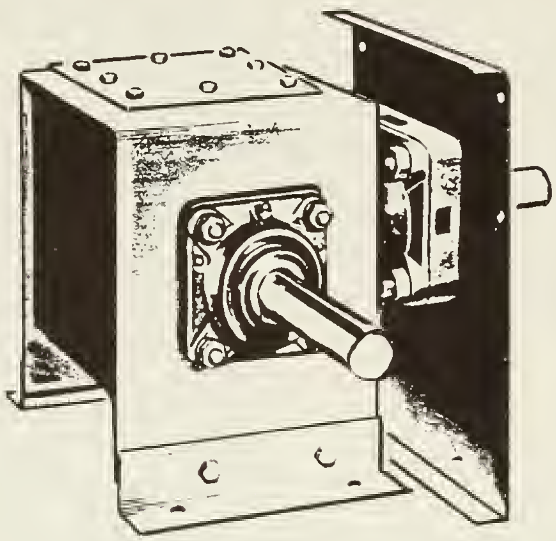


Fig. 13. Enclosed countershaft trough ends.
Source: ***Syntron and link-belt material handling equipment.***

1.21 Trough sections

Bolted flange connections or welded butt straps generally connect trough sections together. The flanged connection has proven to be the most practical and efficient means of connection. Use angle flanges on 300 mm troughs. Troughs 350 mm and larger require plate flanges.

Formed steel supporting feet, used for end flanges, provide convenient support for the conveyor. Saddles offer additional strength where the location of the support points differ from flange connections.

Trough covers contain dust and protect both personnel and the material being handled. Choose from plain, flanged, semi-flanged, or dust seal covers and attach them to the trough with bolts, screw-clamps, or spring-clamps.

1.22 *Seal glands and trough end seals* Seal glands and trough end seals protect bearings from dust or fumes generated within the trough. They also prevent entrance of dirt or moisture along the shaft.

1.23 Troughs

Troughs primarily confine and guide the flow of material. However, they also house and support the operating components by holding them together in their proper functional relationship. Troughs are available in many different shapes (Fig. 14).

In general, troughs that can be fabricated of mild steel can also be made of stainless steel or aluminum, brass, bronze, copper, Monel metal, or nickel. Use stainless steel or nonferrous metal troughs in corrosive or high-temperature applications.

1.24 *Flanged troughs* To obtain strength and rigidity, without superfluous bulk or weight, form the top flanges and the trough sides from a single steel sheet; this is the flanged trough. Then securely weld the steel connecting flanges at each end. This design ensures proper alignment of the troughs and preserves their contour.

1.25 *Angle-flanged troughs* This trough is similar to the flanged trough, except that structural steel angles welded to the trough form the flanges.

1.26 *Dust seal troughs and covers* Z-bar flanges and formed-channel cross members make a continuous channel pocket around the top of the trough into which the flanged cover sections are set. The channel fills with sand or the dust of the conveyed material and creates an effective seal.

1.27 *Flared troughs* The trough sides flare outward creating a top opening wider than that of conventional troughs. This shape improves feeding and conveying actions, especially for materials which are sticky or not free flowing. Use flared troughs with ribbon flight conveyor screws.

1.28 *Drop-bottom troughs* A drop bottom, usually hinged and held in place by spring clamps or quick-acting hand clamps, equips this kind of trough. This configuration permits easy access (for service and maintenance) to the trough interior, to the conveyor screws, and to the hangers.

1.29 *Jacketed troughs* This trough consists of a formed jacket continuously welded to a trough of conventional construction. Use jacketed troughs for applications requiring heating, drying, or cooling of materials. Pipe connections supply and discharge the heating or cooling media to the jacket.

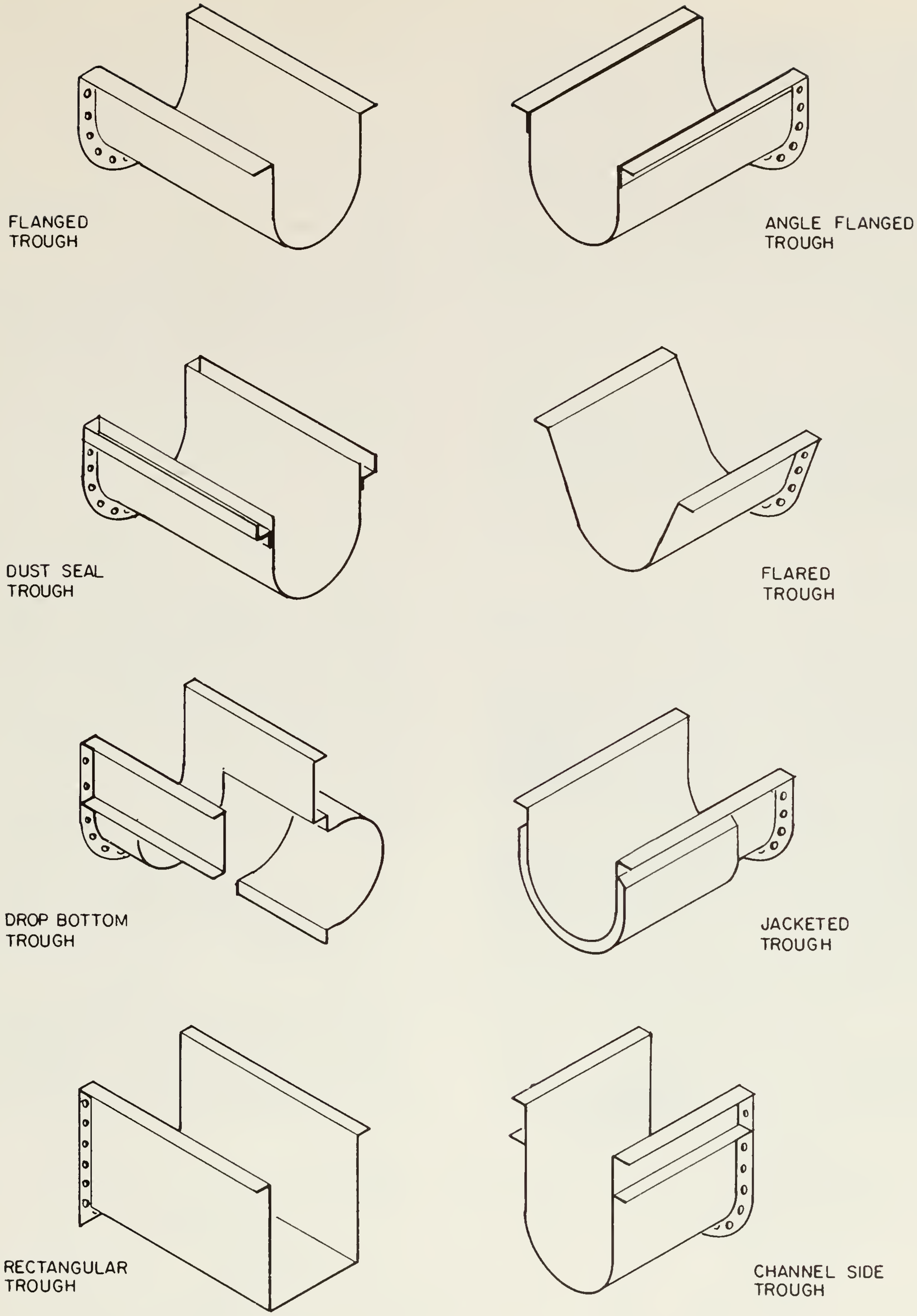


Fig. 14 Trough shapes.
Source: *Screw conveyor engineering catalog no. 7700.*

1.30 *Rectangular troughs* Rectangular troughs generally handle abrasive materials since these kinds of materials form a layer of material on the bottom of the trough. The material thus moves on itself, protecting the trough from excessive wear. Depending on the size and gauge of metal, rectangular troughs may be made from a single steel sheet, or with sides and bottom made from separate pieces.

Rectangular troughs, however, are rarely used in agricultural applications.

1.31 *Channel-section troughs* This trough is made with separate, detachable trough bottoms bolted or clamped to steel channels. The channels may be of any reasonable length to span widely spaced supports. Trough bottoms are limited to a maximum of 3.7 m.

Like rectangular troughs, channel section troughs are rarely used in agricultural applications.

1.32 Shrouds

U-shaped trough sections of screw feeders rely on shrouds to obtain proper feed regulation. Shrouds accomplish this by decreasing the clearance between the cover and feeder screw (Fig. 15).

1.33 Trough discharge spouts and gates

Conveyed material discharges from troughs or passes into succeeding equipment via discharge spouts and gates.

Gates provide selective control of the delivery locations. Use slide gates or rack-and-pinion gates since they suit practically all applications and can operate either parallel or perpendicular to the conveyor. Hydraulic, electric, or pneumatic controls operate the gates.

1.34 *Trough spouts* Feed and discharge openings can be plain or flanged and can be mounted at almost any point on the conveyor (Fig. 16). Install feed spouts at least one conveyor diameter from the conveyor tail end to protect the bearing.

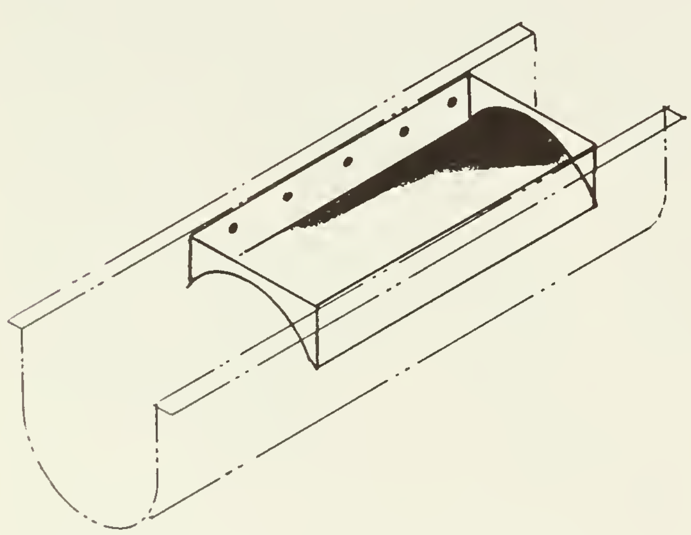


Fig. 15. U-trough shape.

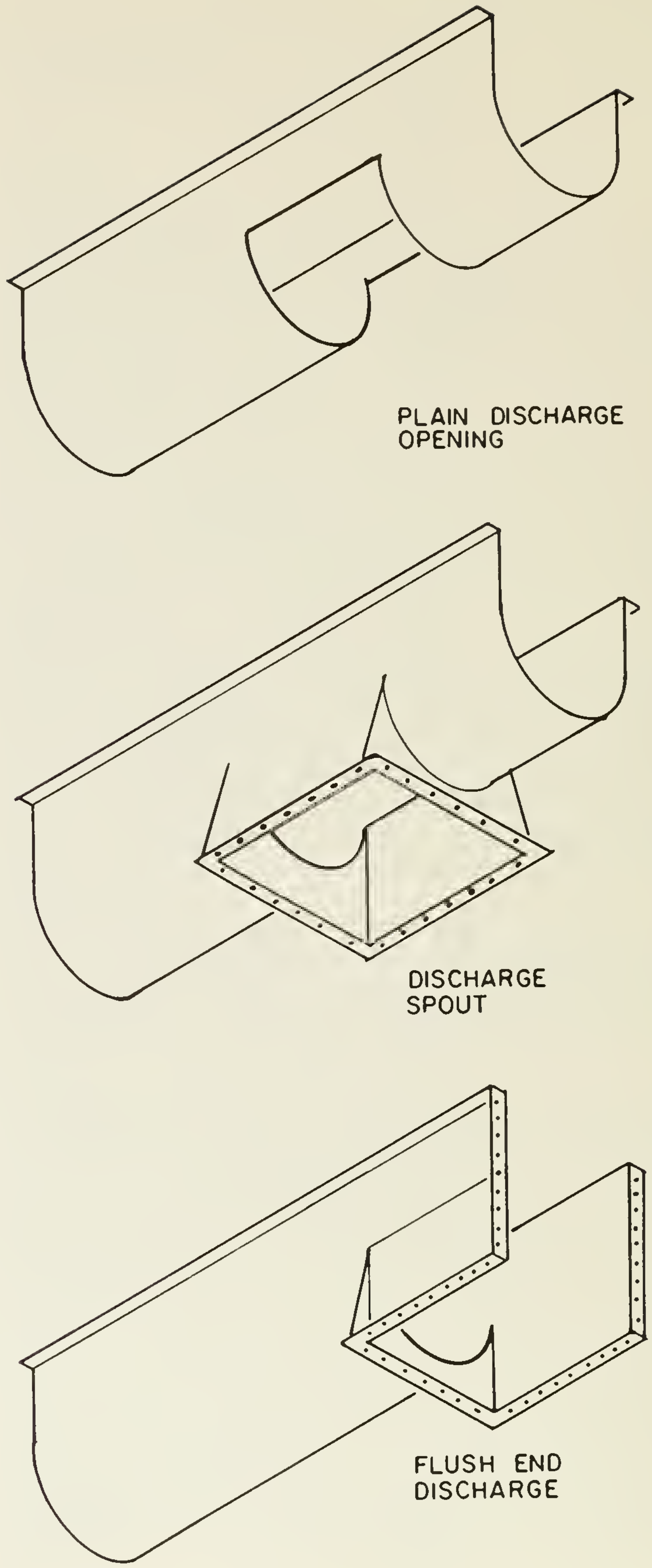


Fig. 16. Trough spouts.

1.35 *Slide gates* Slide gates attach to discharge spouts and operate from any one of the four sides. The design, however, must provide sufficient clearance for the open gate and the power operator, if used (Fig. 17).

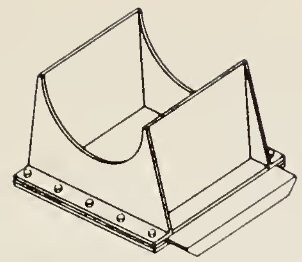


Fig. 17. Slide gate.

1.36 *Rack-and-pinion slide gates* Rack-and-pinion slide gates have cut-tooth racks welded to the slide plates. Cut-tooth pinions mounted on pinion shafts cause the gates to slide parallel to the conveyor (Fig. 18).

Curved rack-and-pinion slide plates, fitted to the contour of the troughs, eliminate pockets typically formed by flat slide plates.

2 FARM AUGERS

Farm augers are specialized screw conveyors that generally require no internal bearings. The screw operates at high speed—300–800 r/min, depending on diameter—in a tubular casing. Wheels, generally mounted on farm augers, enhance their portability. The undercarriage provides incline adjustment so the grain can be elevated into bins or other holding areas. Swing-type feed hoppers, available for some auger models, facilitate truck unloading. Farm augers can also be supplied with cleaning accessories.

Augers are available in lengths up to 24 m and in diameters 100–400 mm. The largest can elevate 130 m^3/h of grain to heights of 15 m or more.

Tractor power takeoff (PTO) generally drives the larger augers. PTO, gas, hydraulic, or electric motor drives will power smaller augers. A line shaft from the base supplies the power to the discharge end of the auger. This configuration puts the screw shaft in tension to eliminate buckling loads and to reduce member sizes. Flexible connectors on the line shaft accommodate flexing of the auger tube.

Farm augers operate much faster than hanger-bearing screw conveyors, but the screw must be choke fed. Running the auger screw empty accelerates equipment wear. Operating at less than full capacity may cause excessive grain damage.

To overcome friction between the flighting and the grain against the tube wall, farm augers require large power supplies. As well, power requirements increase dramatically when handling wet grain. For example, an auger fully loaded with wet grain requires 2 to 3 times the starting torque, compared with the same system handling dry grain.

Farms and other agricultural facilities rely on high-speed augers for bin unloading and grain distribution.

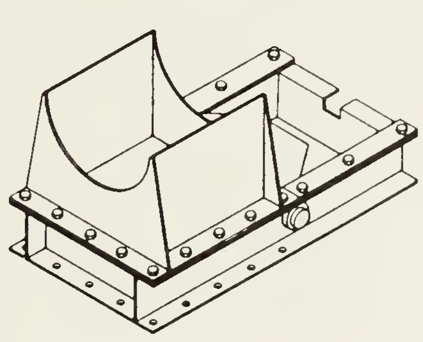
2.1 Specialty conveyors

A class of screw conveyor without a centre shaft is also available. They are very flexible and operate without special couplings around formed corner elbows. The flighting itself transmits the torque and is held in position by a rigid conduit or tube.

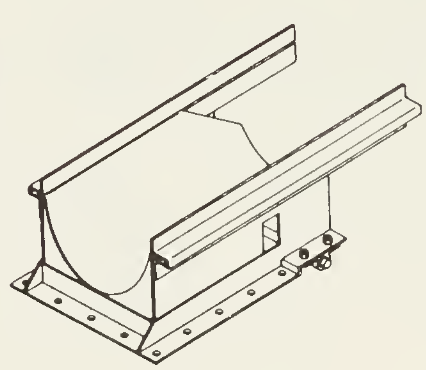
These specialty conveyors usually measure 100 mm or less in diameter. Use them in applications handling feed and ground products. Contact the suppliers for sizing and power requirements.

3 SELECTING CONVEYOR CAPACITY AND SPEED

Use the characteristics of the material to be conveyed to establish the conveyor capacity and speed (Table 1). Set the loading to the



FLAT SLIDE GATE



CURVED SLIDE GATE

Fig. 18. Rack-and-pinion slide gates.

Table 1 Agricultural material characteristics

Material	Bulk density (kg/m³)	% Load	Material factor (*m*)	Remarks
Alfalfa				
meal	290	30*A*	36	oily
pellets	673	30*A*	36	–
seed	192	45	30	–
Ammonium nitrate	800	30*A*	78	explosive, corrosive
Ammonium sulfate	880	30*A*	60	builds up
Barley				
ground	560	30*A*	24	–
malted	560	30*A*	24	–
meal	448	30*A*	24	–
whole	640	30*A*	30	–
Beans				
castor, meal	608	30*A*	48	oily
castor, shelled	576	45	30	oily
navy, dry	767	45	30	–
navy, steeped	961	45	48	–
Bone ash	721	30*A*	96	–
Bran				
rye, wheat	288	30*B*	30	–
Brewer's grain				
spent dry	352	30*A*	30	–
spent wet	924	30*A*	48	–
Buckwheat	610	45	24	–
Clover seed	752	45	24	–
Corn				
cracked	721	45	42	–
cobs, ground	272	45	36	–
germ	336	30*A*	24	fluffy
Corn				
grits	689	30*A*	30	–
meal	576	30*A*	30	oily
seed	700	45	24	–
shelled	700	30*A*	24	–
sugar	529	30*A*	60	–

(continued)

Table 1 **Agricultural material characteristics** *(continued)*

Material	Bulk density (kg/m³)	% Load	Material factor (*m*)	Remarks
Distiller's grain				
spent dry	480	30*A*	30	–
spent wet	801	30*A*	48	–
Egg powder	256	30*A*	60	–
Fish meal	609	30*A*	60	–
Flax seed	650	30*A*	24	packs
Flax seed				
cake	785	30*A*	42	oily
meal	561	30*A*	24	oily
Flour wheat	593	30*A*	36	very dusty
Gluten, meal	641	30*A*	36	–
Hops				
spent dry	561	30*A*	60	–
spent wet	849	30*A*	90	agglomerate
Lactose	513	30*A*	36	–
Limestone				
agricultural	1089	30*A*	120	–
Malt				
dry ground	400	30*A*	30	–
meal	609	45	24	–
dry whole	400	30*A*	30	–
sprouts	222	30*A*	24	–
Mustard seed	721	45	24	–
Oats	416	30*A*	24	–
Oats				
hulls	160	30*A*	30	–
Rye	721	45	24	–
Safflower seed	721	45	24	–
Soybean				
cake	673	30*A*	60	oily
meal, cold	641	30*A*	30	–
meal, hot	641	30*A*	30	corrosive

(continued)

Table 1 **Agricultural material characteristics** ***(concluded)***

Material	Bulk density (kg/m³)	% Load	Material factor (*m*)	Remarks
Starch	609	45	60	aerates
Timothy seed	577	30*A*	36	–
Triple super	849	30*B*	120	corrosive, toxic
Wheat	735	45	24	–
Wheat, cracked	689	45	24	–

1 Dry grains, seeds, and agricultural products generate dust when handled. This dust explodes under certain conditions.
2 For characteristics of other products, refer to CEMA standards or manufacturer's literature.
3 If grain, seed, or any dry material is handled wet, multiply the material factor by 1.35 to accommodate for the power increase required. (See section 2 Farm augers.)
4 The letters *A* and *B* in the Load density column designate CEMA size classification as follows:
A very fine – 100 mesh and under
B fine – 3.2 mm to 100 mesh

Source: *Screw conveyor engineering catalog no. 7700.*

maximum percentage of the screw cross section occupied by the material. Loadings vary from 15–45%, depending upon the material properties. Use the material factor (*m*) in determining power requirements.

To determine the size and speed of a screw conveyor, first use Table 2 to derive the trough loading for the type of material to be handled. This table lists the required capacity in cubic meters per hour for various-sized screw conveyors operating at one revolution per minute (r/min) under four cross-sectional loadings. It also presents the maximum recommended speeds as well as the recommended capacity at those speeds.

The data listed in Table 2 relate to standard conveyors used in industry. Under industrial conditions, volumetric feeders control conveying rates as material is uniformly fed into and discharged from the conveyor.

3.1 Screw conveyor speed

For regular-pitched, helical-flight conveyors determine the conveyor speed (V_c) by the formula:

$$V_c = \frac{\text{required capacity (m}^3\text{/h)}}{\text{capacity (m}^3\text{/h) at 1 r/min}}$$

To calculate conveyor speeds at other pitches or for different types of screws, use the equivalent capacity (Q_e). The equivalent capacity involves calculation of three important parameters: the pitch factor (P), the loading correction factor (C), and the inclination factor (I).

3.2 *Conveyor pitch factor (P)* The pitch factor depends on whether the screw is rated standard, short, half-pitch, or long.

Standard:	Pitch =	screw diameter
	P =	1.00
Short:	Pitch =	0.67 screw diameter
	P =	1.50
Half:	Pitch =	0.5 screw diameter
	P =	2.00
Long:	Pitch =	1.5 screw diameter
	P =	0.67

Source: *Sullivan Strong Scott Catalog no. 7700.*

3.3 *Loading correction factor (C)* For a ribbon flight conveyor at various loadings use these correction factors:

C = 1.04 for 15% loading

C = 1.37 for 30% loading

C = 1.62 for 45% loading

3.4 *Inclination factor (I)* For inclined conveyors use the following inclination factors (as developed by the FMC Corporation, Material Handling Equipment Division):

$I = 1.11$ for 10° conveyor angle

$I = 1.18$ for 15° conveyor angle

$I = 1.82$ for 20° conveyor angle

$I = 2.38$ for 25° conveyor angle

$I = 4.55$ for 35° conveyor angle

On inclines up to 35° use standard pitch. However, half-pitch flighting is recommended for inclines steeper than 25°. Avoid ribbon flight screws on inclined augers.

3.5 *Equivalent capacity* To calculate equivalent capacity (Q_e):

Q_e = Required capacity $\times P \times C \times I$

3.6 Material lump size

Most conveyors can handle lumpy materials. Select the conveyor so the maximum lump size is 15% of the flight diameter. If more than 25% of the material present is larger than half of the maximum lump size, consult the conveyor manufacturer.

3.7 Sample problem: calculating conveyor speed

Determine the required conveyor speed (V_c) for a short pitch, 20° inclined conveyor running 30% full and which must deliver dry Brewer's grain at a rate of 15 t/h.

From Table 1, the density of the grain is 352 kg/m^3.

$$\text{Required capacity} = \frac{15\,000 \text{ kg/h}}{352 \text{ kg/m}^3} = 42.6 \text{ m}^3\text{/h}$$

$$\text{Equivalent capacity} = Q_e = 42.6 \times P \times I = 42.6 \times 1.5 \times 1.82 = 116.3 \text{ m}^3\text{/h}$$

From Table 2 select a 500-mm-diameter conveyor with a capacity of 123.9 m^3/h at the maximum rotational speed.

$$V_c = \frac{116.3 \text{ m}^3\text{/h}}{1.77 \text{ (m}^3\text{/h)/(r/min)}} = 66 \text{ r/min}$$

When using hard iron bearings, however, calculate the maximum recommended operating speed as follows:

$$V_s = \frac{3048}{\text{shaft diameter (mm)}}$$

where V_s = screw operating speed (r/min)

Table 2 Horizontal screw conveyor specifications

Load class	Conveyor diameter (mm)	Industrial conveyors maximum speed (r/min)	Capacity (m^3/h) at maximum speed	Capacity (m^3/h) at 1 r/min
45%	100	175	3.1	0.018
	150	165	11.0	0.063
	225	155	36.0	0.232
	250	150	46.3	0.31
	300	145	78.8	0.55
	350	140	123.7	0.88
	400	130	171.9	1.32
	450	120	229.7	1.91
	500	110	291.8	2.65
	600	100	464.3	4.64
30A%	100	140	1.7	0.012
	150	120	5.1	0.042
	225	100	15.4	0.154
	250	95	19.4	0.204
	300	90	32.9	0.365
	350	85	50.0	0.589
	400	80	70.7	0.883
	450	75	95.6	1.27
	500	70	123.9	1.77
	600	65	200.8	3.09
30B%	100	75	0.9	0.012
	150	65	2.7	0.042
	225	55	8.5	0.154
	250	55	11.2	0.204
	300	50	18.3	0.365
	350	50	29.5	0.589
	400	45	37.5	0.889
	450	45	57.2	1.27
	500	40	70.8	1.77
	600	40	123.6	3.09
15%	100	70	0.42	0.006
	150	60	1.3	0.21
	225	55	4.2	0.077
	250	55	5.8	0.105
	300	50	10.1	0.183
	350	50	14.7	0.294
	400	45	19.9	0.442
	450	45	28.7	0.637
	500	40	35.3	0.883
	600	40	61.8	1.55

Source: *Syntron and link-belt material handling equipment.*

The maximum rotational speeds listed in Table 2 are for hanger bearing augers. For farm augers, the capacity equals the displacement at 1 r/min (assuming 85% loading) times the actual rotational speed. Eighty-five percent loading is attainable, however, only with adequate exposed flighting at the intake. On farm augers currently available the length of exposed flighting varies:

330 mm for 150 mm diameter

400 – 450 mm for 200 mm diameter

900 – 1100 mm for 250 mm diameter.

3.8 Power requirements for screw conveyors

Two factors influence the power required to operate a screw conveyor: the type of installation and the uniformity of feed rate.

The power requirement at the drive shaft of a screw conveyor equals the sum of the power required to overcome bearing friction plus the power required to convey the material. Use this formula to calculate the power requirement for a standard flighting conveyor:

$$P_s = \frac{gL(b \times V_s + Q_e \times m)}{30\,300}$$

where P_s = shaft power (kW)

g = gravitational constant ($9.81\ m/s^2$)

L = length of conveyor (m)

b = hanger bearing friction factor (see Table 3)

V_s = operating speed (r/min)

Q_e = equivalent capacity (kg/s)

m = material factor (see Table 1)

When elevating material, add the following power factor to the horizontal power requirement:

$$P_i = \frac{g\,Q_e\,h}{10^3}$$

where P_i = incline component of shaft power (kW)

h = vertical lift (m)

If the conveyor flighting deviates in pitch only, power requirements are not affected. However, modified flighting requires additional power. Determine the total power required by the following formula:

$$P_m = M(P_s + P_i)$$

where P_m = power for modified flighting (kW)

M = modified flighting factor (see Table 4)

Table 3 Hanger bearing friction factors (b)

	Type of hanger bearings			
Screw diameter mm	Ball or roller	Wood, babbitt, or bronze	Nylon	Hard iron
100	0.09	0.16	0.19	0.38
150	0.14	0.25	0.29	0.60
200	0.20	0.35	0.43	0.84
250	0.29	0.50	0.60	1.21
300	0.42	0.73	0.87	1.89
350	0.59	1.02	1.24	2.65
400	0.80	1.41	1.70	3.63
450	1.06	1.81	2.22	4.54
500	1.25	2.15	2.61	5.29
600	1.74	2.95	3.67	7.18

Source: *Screw conveyor engineering catalog no. 7700*

Table 4 Modified flighting factors

	Conveyor loading			
Flight type	15%	30%	45%	95%
Cut flight	1.10	1.15	1.20	1.30
Cut and folded flight	N.R.	1.50	1.70	2.20
Ribbon flight	1.05	1.14	1.20	–

N.R. = not recommended

Source: *Screw conveyor engineering catalog no. 7700*

When selecting a motor, modify the rated power by an efficiency factor to ensure adequate power to the conveyor. Most designers use a drive efficiency factor (e) of 0.75 if manufacturers' figures are not available.

Calculate motor power this way:

$$P_M = P_{st}/e$$

where P_M = motor power (kW)

P_{st} = total shaft power (kW) for horizontal, inclined, standard or modified flighting

e = drive efficiency factor

Farm augers rotate much faster than shown in Table 2. For augers 100–150 mm in diameter, the maximum speed is 800 r/min; augers of 200 mm diameter rotate at 600 r/min; and the speed of rotation for 300-mm-diameter augers is 300 r/min. Auger wear, grain damage, and power requirements limit rotational speed.

Estimate the power requirements for farm augers by multiplying the material factor (m) shown in Table 1 by three and applying this value in the formulas for shaft power (P_s) and inclined shaft power (P_i).

Screw conveyors are designed to industrial standards. Select them to perform under industrial conditions for specific flow rates. Farm augers are designed for a lower life expectancy and a greater potential for down time. They operate at higher speeds and have smaller shaft diameters than industrial screw conveyors.

3.9 Sample problem: screw conveyor motor size

Calculate the motor size required for the screw conveyor as in the sample problem detailed in section 3.3. The conveyor is 20 m long and uses roller bearings.

$$P_s = \frac{gL(b \times V_c + Q \times m)}{30\,300}$$

where
P_s = shaft power
g = 9.81 m/s^2
L = 20 m
b = 1.25 (see Table 3)
V_c = 66 r/min

$$Q = \frac{15\,000 \text{ kg/h}}{3600 \text{ s/h}} = 4.2 \text{ kg/s}$$

m = 30

$$P_s = \frac{9.81 \times 20\,(1.25 \times 66 + 4.2 \times 30)}{30\,300} = 1.35 \text{ kW}$$

To account for 20% inclination:

$$P_i = gQh/10^3$$

where $h = 20 \sin 20° = 6.8$ m

$$P_i = \frac{9.81 \times 4.2 \times 6.8}{10^3} = 0.3 \text{ kW}$$

Total shaft power:

$$P_{st} = P_s + P_i = 1.35 + 0.3 = 1.65 \text{ kW}$$

Required motor power:

$$P_M = P_{st}/e = \frac{1.65}{0.75} = 2.2 \text{ kW}$$

3.10 Screw feeder operating parameters

Screw feeders demonstrate very different design and power parameters than screw conveyors. The screw feeder usually has tapered or variable pitch flighting at the inlet opening to draw material as uniformly as possible from across the feeder bin. A choke section, immediately downstream of the inlet opening, operates 100% full and meters the material flowing from the bin. Beyond the choke section, the trough has a flat cover that allows room for the material to expand slightly. This cover also provides access to the screw for maintenance (Fig. 19).

Operational speeds depend on the type of material being handled and on the feeder diameter. Since the screw feeder runs full, it

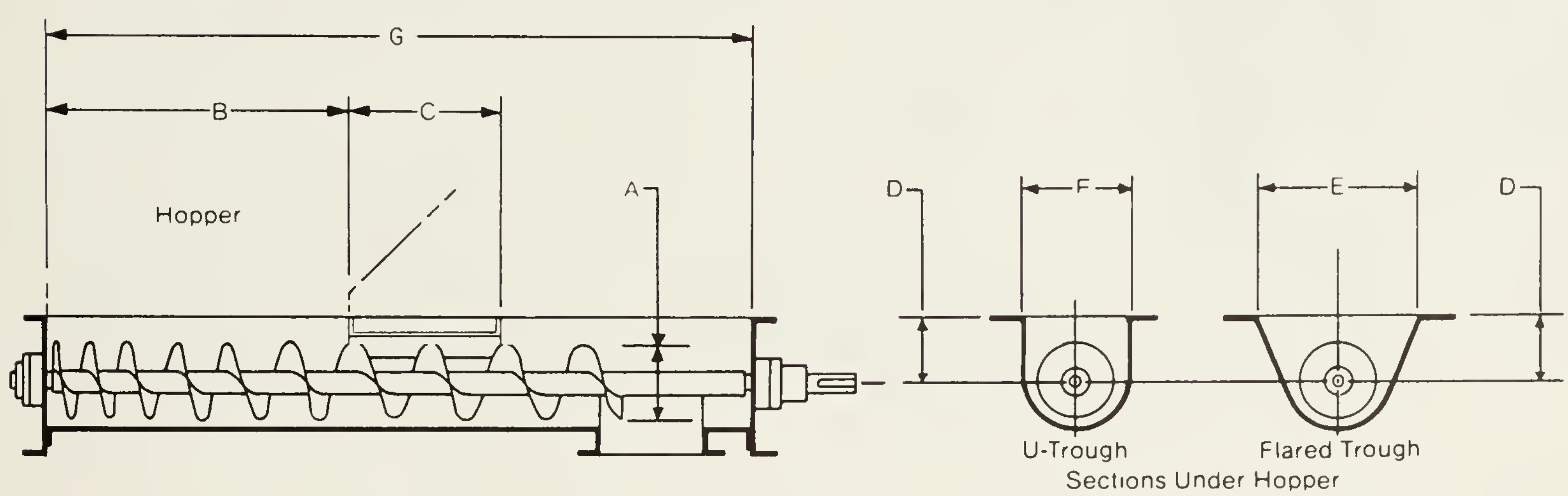


Fig. 19. Screw feeder components. *A*, auger diameter; *B*, hopper length; *C*, choke length; *D*, trough height above shaft; *E*, flared trough width; *F*, U-trough width; *G*, trough length.
Source: *Syntron and link-belt material handling equipment.*

Table 5 Screw feeder capacities for agricultural materials

Feeder diameter (mm)	Maximum speed (r/min)	Capacity at maximum speed (m^3/h)	Capacity at 1 r/min (m^3/h)
100	275	10.2	0.037
150	240	33.8	0.141
225	230	120	0.524
250	225	153	0.680
300	220	277	1.26
350	215	426	1.98
400	190	562	2.96
450	170	728	4.28
500	150	888	5.92
600	120	1236	10.3

Source: *Syntron and link-belt material handling equipment.*

requires considerably more power than a screw conveyor. Table 5 lists horizontal screw feeder capacities for various feeder diameters. Use this table to calculate screw feeder operating speeds.

Calculating the power required to operate a screw feeder relies on many of the same equations as do calculations for screw conveyors. However, substitute conveyor length (L) with an equivalent length (L_e). Determine the equivalent length using Tables 6 and 7 along with Figs. 19 and 20.

Table 6 Screw feeder dimensions

A	*B*	*C*	*D*	*E*	*F*
100	600	200	125	250	125
150	900	300	180	355	180
225	1050	450	230	460	255
250	1100	525	240	480	290
300	1200	600	250	560	330
350	1300	710	280	610	380
400	1400	810	290	710	430
450	1450	910	310	790	480
500	1500	1000	340	860	530
600	1625	1200	420	1020	635

A = diameter (mm)
B = throat length (mm)
C = choke length (mm)
D = distance from the centre of the auger to the top of the trough (mm)
E = width of a flared trough (mm)
F = width of a u-shaped trough (mm)

These are approximate dimensions, taken from an average of typical installations. Verify them against the actual installation. Refer to Figs. 19 and 20.

Source: *Syntron and link-belt material handling equipment.*

4 BUCKET ELEVATORS

Bucket elevators are widely used in the vertical transport of free-flowing, granular agricultural materials. Buckets bolted to a continuous belt pick up the material and move it within a dust-tight casing or leg.

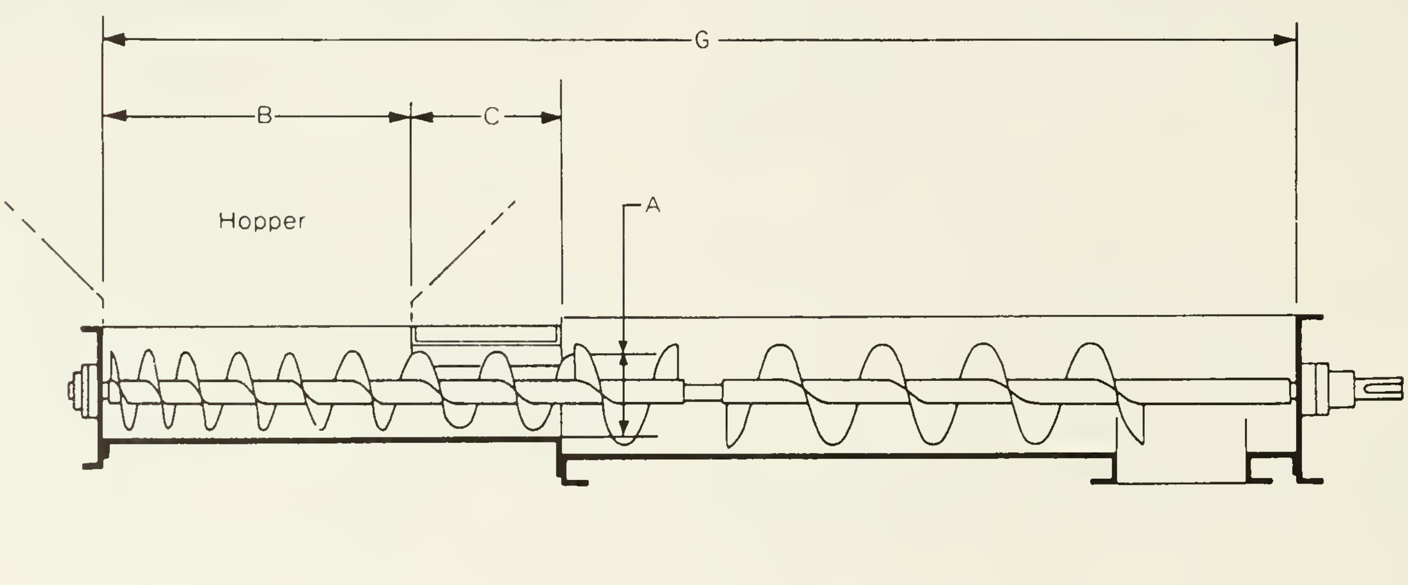


Fig. 20. Screw feeder with extension conveyor. *A*, auger diameter; *B*, hopper length; *C*, choke length; *G*, trough length.
Source: *Syntron and link-belt material handling equipment.*

Table 7 Screw feeder equivalent length (L_e) based on feeder selection

Type of material	Type of screw under feed opening	Equivalent length (L_e)
Under 3.2 mm	tapered	$G + B + C$
Under 3.2 mm	straight	$G + 2B + C$
3.2–12 mm	tapered	$G + 2B + C$
Over 12 mm	tapered	$G + 3B + C$

G = length of the trough (mm) (Fig. 20)

Source: *Canadian feed manufacturing technology*

The buckets pick up material near the bottom, or boot, of the elevator. Grain generally feeds into the elevator on the up-leg, where it fills the buckets on their upward travel. Ground stock, or fine materials fill the buckets on the down-leg. The digging action of the buckets fills them as they pass through the boot section of the elevator.

Gravity and centrifugal force at the head of the elevator cause the material to discharge from the buckets as they pass over the head pulley. A chute mounted on the lower side of the head assembly carries the material away.

Power is normally supplied to the head shaft. Adjustment for belt tension is provided at the boot pulley. Only belt strength limits the elevator height.

Fig. 21 shows a typical bucket elevator and its principle parts.

The advantages of bucket elevators include:

- wide range of available capacities
- low maintenance
- good mechanical efficiency
- minimal floor space requirements
- dust-free operation
- low operating cost
- quiet operation
- ability to run empty without damage
- close spacing of bins

Among the disadvantages:

- material damage
- boot cleaning requirements
- high capital costs

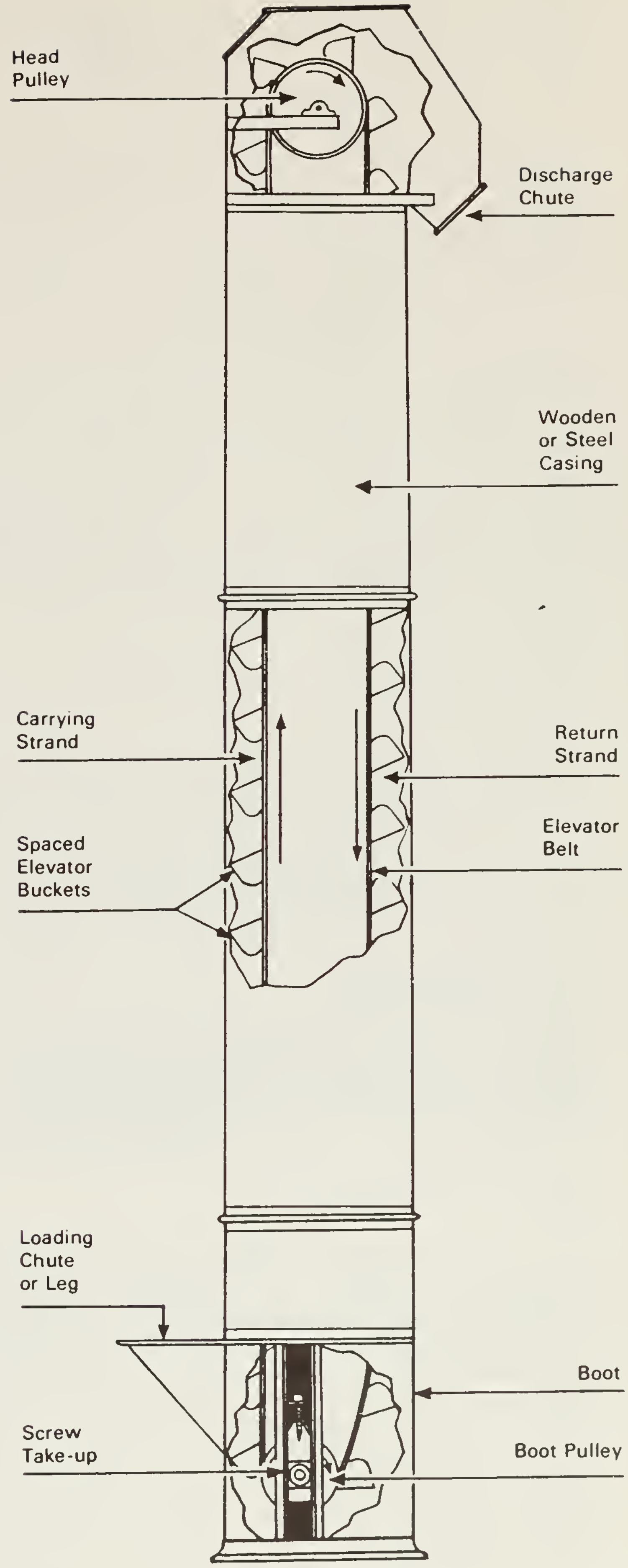


Fig. 21. Bucket elevator.
Source: *Grain handling and storage.*

4.1 Power requirements

Use the following formulas to estimate the power requirements for a bucket elevator:

$$P = \frac{F_1 Q g h}{1000}$$

where P = power (kW)

Q = amount of material conveyed (kg/s)

g = gravitational constant (9.81 m/s^2)

h = lift (m)

F_1 = loading factor

The loading factor (F_1) accounts for friction and digging forces. When material is being fed on the up side of the elevator, $F_1 = 1.2$. When loading on the down side of the elevator, $F_1 = 1.5$.

Motor power required

$$P_M = P / e$$

where P = power (kW)

e = drive efficiency factor, as specified by the manufacturer

= 0.75, if manufacturers' specification not available

4.2 Drive arrangements

Bucket elevators generally use a belt-driven gear reducer mounted on the shaft to drive the head pulley. Small elevators sometimes use jackshaft drives. Parallel shaft reducers connect to the head shaft, either directly or with a final chain drive.

Hydraulic drives can supply power to bucket elevators to provide the slow rotation speeds required. However, gear reducer motor drives are generally more economical. Creep drives, which provide slow rotational speed to empty elevator legs, allow for drive inspections.

Backstops prevent reverse rotation of the elevator when it stops under load. Mount the backstop internally in the reducer, or directly on the head shaft.

4.3 Operational speed

Bucket size and spacing establish the operational speed and the capacity of bucket elevators. The head pulley speed influences effective discharge and, if uncontrolled, causes material damage. Belt speed depends on the head pulley diameter and rotational speed.

According to the Goodyear theory of centrifugal discharge, the optimum head pulley rotational speed can be calculated using the following formula:

$$V_p = \frac{30}{\sqrt{R \tan(60 - \phi)}}$$

where V_p = head pulley speed (r/min)

R = head pulley radius (m)

ϕ = emptying angle of repose of the material being transported

The U.S. Department of Agriculture states that the emptying angle of repose for various grains averages 28.4°. Using this value, the formula becomes:

$$V_p = \frac{38}{\sqrt{R}}$$

Note that bucket shape affects the optimum head speed, so use the calculated value as a guide only. Actual operating speeds can vary 20% from the calculated optimum.

After determining the rotational speed of the head pulley, calculate the belt velocity with this formula:

$$V = \frac{\pi D V_p}{60}$$

where V = belt velocity (m/s)

D = head pulley diameter (m)

4.4 Bucket elevator capacity

Calculate bucket capacity using the following formula:

$$Q = \frac{Q_u B V}{n}$$

where Q = capacity (kg/s)

Q_u = usable bucket capacity (m^3)

B = bulk density of material (kg/m^3)

n = bucket spacing on the belt (m)

Most buckets fill to 75%. Thus, the usable bucket capacity is three-quarters of the gross capacity.

Consult the suppliers' literature for capacities of the various styles of buckets.

4.5 Sample problem: elevator power

Consider a 15-m bucket elevator feeding on the up side and handling wheat with 9 × 6 buckets. The volume of each bucket measures

3.5 L. The buckets are arranged in a single row and spaced at 0.2 m. The head pulley has a diameter of 0.760 m. Calculate:

- head pulley speed, V_p
- belt velocity, V
- elevator capacity, Q
- motor power, P_M

Head pulley speed:

$$V_p = \frac{38}{\sqrt{R}} = \frac{38}{\sqrt{0.38}} = 62 \text{ r/min}$$

Belt velocity:

$$V = \frac{\pi D V_p}{60} = \frac{\pi(0.76)(62)}{60} = 2.47 \text{ m/s}$$

Elevator capacity:

$$Q = \frac{Q_u B V}{s} = \frac{0.75 \times 0.0035 \times 735 \times 2.47}{0.200} = 23.8 \text{ kg/s}$$

Power:

$$P = \frac{F_1 Qgh}{1000} = \frac{1.2 \times 23.8 \times 9.81 \times 15}{1000} = 4.2 \text{ kW}$$

Motor power:

$$P_M = \frac{4.2}{0.75} = 5.6 \text{ kW}$$

4.6 Head details

Select the head pulley diameter to measure 4 or 5 times the distance the bucket projects from the belt surface. The pulley face is at least 25 mm greater than the belt width. Common belt designs include rough-topped, or bolted, segmented sections.

Crown head pulleys with a taper of 0.01 to keep the belt tracking close to the centre. In addition, lag the head pulleys to reduce the belt's tendency to slip under the load of the buckets. Vulcanize, glue, or bolt the lagging surfaces to the head pulley. Mount the head pulley on the head shaft using tapered bushings to facilitate maintenance.

Shape the elevator head section to catch and direct the grain discharged from the buckets. The shape of the bonnet and the position of the discharge throat are also important elements in the design of a bucket elevator system. Good bonnet design allows efficient material discharge and minimizes damage to the material. Match the shape of the elevator head to the product trajectory, as closely as possible. In addition, provide the discharge area with abrasion-resistant liners made of steel, rubber, or polished plastic.

Equip the head section with access doors and a service platform. These components aid inspection and maintenance of the head pulley, discharge throat, and bucket elevator drive. An access door in the discharge throat permits inspection of liners and removal of tramp materials. Often the head section or adjacent structures support the service platform which has ladder access. It is useful to connect the ladder to the elevator casing or trunking and provide a frame for hoisting belting or drives to the top of the elevator. Fig. 22 illustrates these head frame details.

4.7 Boot details

The diameter of the boot and head pulleys is equivalent. Determine the minimum boot pulley size from manufacturers' data on operating belt tensions. Gravity or screw take-ups supply the required belt tension, with screw takeups more common on smaller units.

The product feeds into the elevator boot section. Access doors allow inspection of the boot pulley. Cleanout doors allow removal of material from the base of the boot.

Three designs for cleanout doors are particularly useful.

- Use removable panels set at 45° to the boot pulley. These panels should clear the buckets in their lowest position by at least 20 mm (Fig. 23).

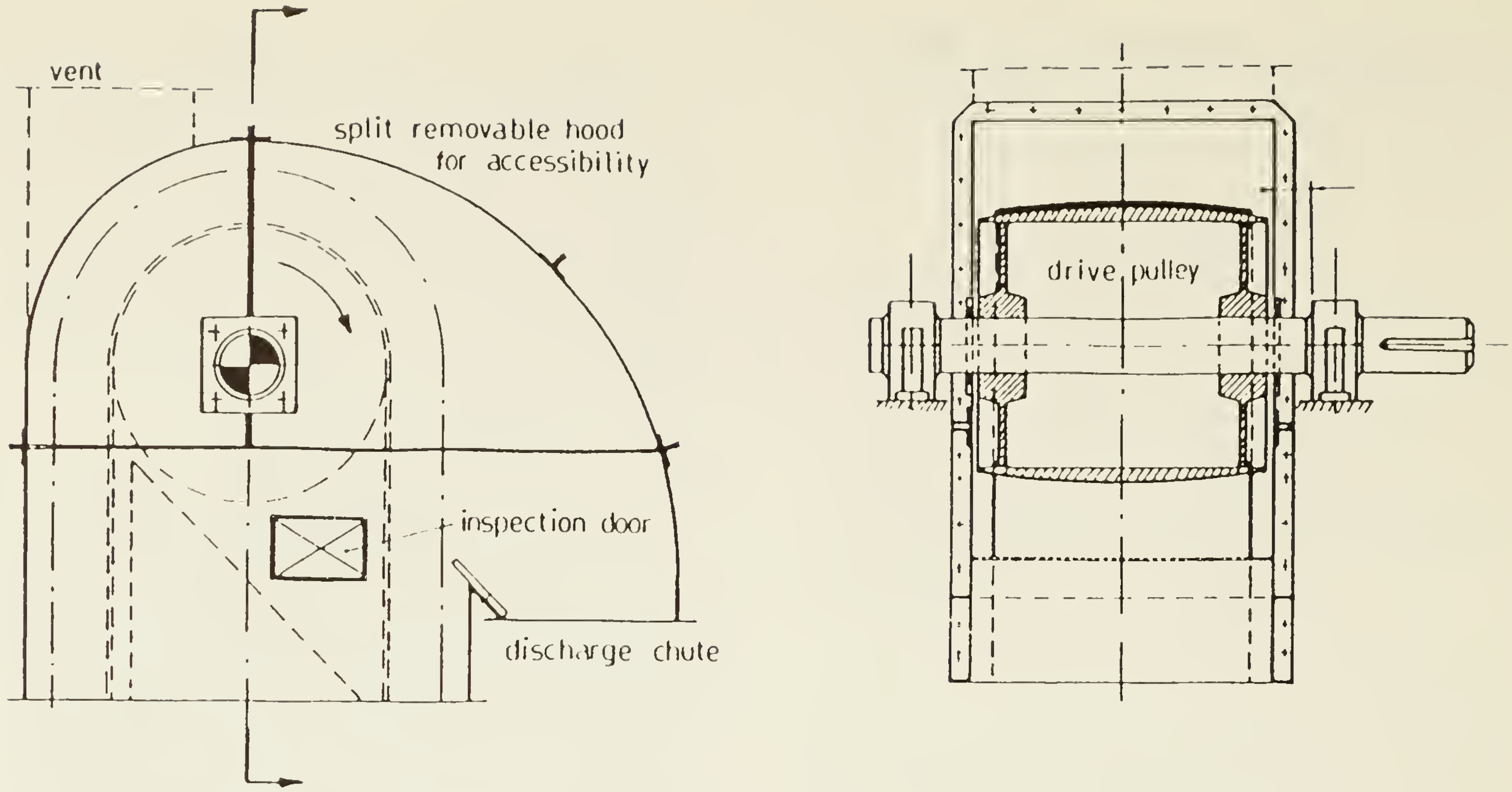


Fig. 22. Bucket elevator head details.
Source: *Grain handling and storage.*

- Adjust the removable panel or panels to conform to the arc of the bucket tip travel. Make these panels adjustable in vertical height to compensate for the belt adjustment. Maintain them at a minimum clearance of 20 mm from the bucket tips.
- Install a full-width slide gate in the base of the boot and elevate it above the supporting floor. With the slide-gate removed, any material in the boot falls to the floor for removal. This configuration guarantees complete cleanout, but can lead to a significant loss of material.

Where contamination is not a problem, choose the second alternative for a cleanout door. When cross contamination may occur, select the first or the third design option. Use the third design in seed plants which require complete cleanout of the boot.

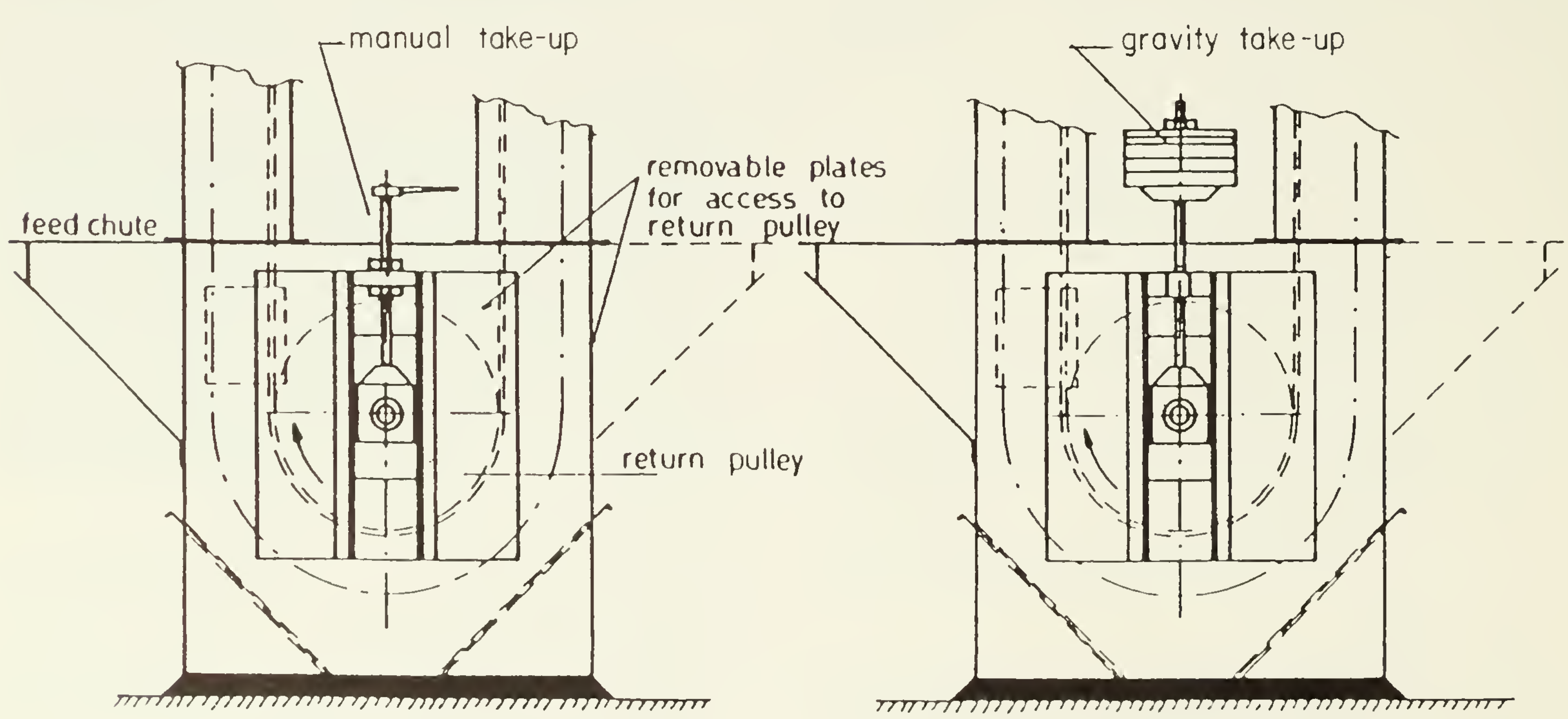
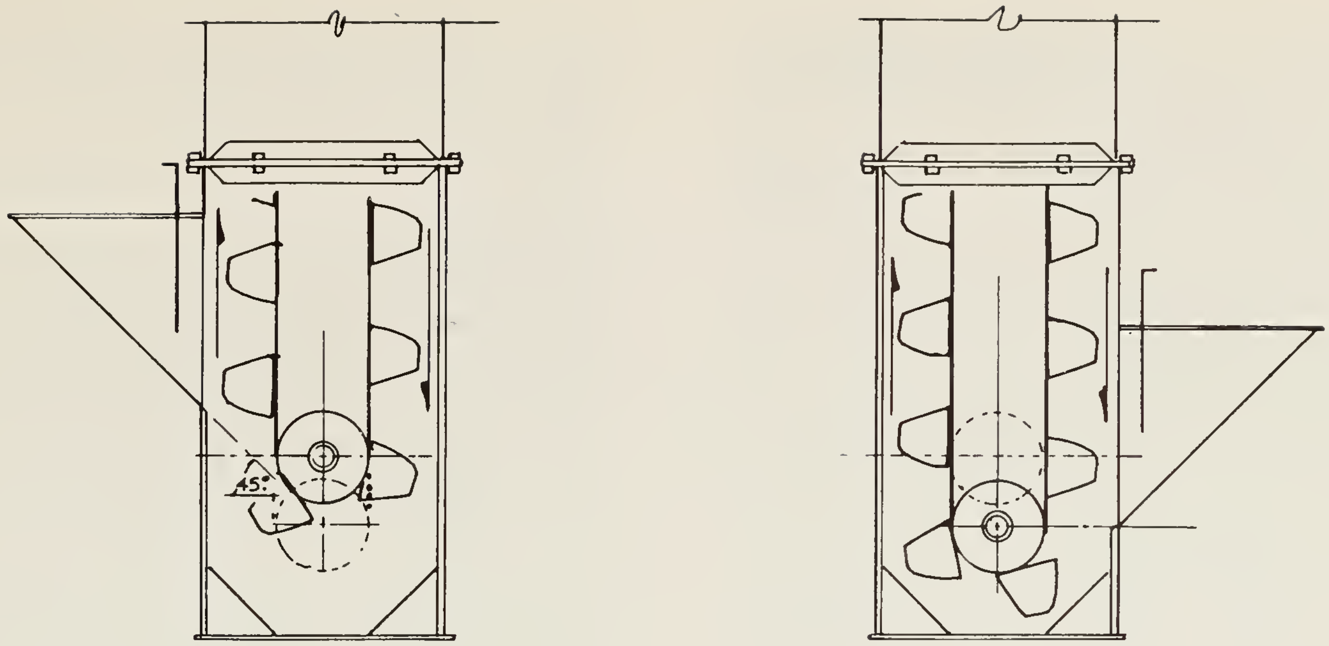


Fig. 23. Bucket elevator boot details.



A B

Fig. 24. Inlet positions for gravity-fed bucket elevators. (A) Up-leg feeding position. (B) Down-leg feeding position.

4.8 Loading

Grain feeds into the elevator at the boot section, preferably into the up leg. This arrangement minimizes both material damage and power requirements. Keep the bottom of the feed hopper above the centre line of the boot pulley in its highest position when feeding the up leg (Fig. 24*a*). When feeding the down leg, maintain the bottom of the feed hopper as low as the centre line of the pulley at its lowest position to avoid material damage (Fig. 24*b*).

Regulate feed to the boot. When relying on gravity feeding, use gates for flow control. Alternatively, screw, belt, or drag conveyors can force feed grain into the elevator, discharging material either directly into the hopper or from a conveyor discharge chute.

When force feeding directly into the elevator, use a hangerless type of screw. Flighting tipped with teflon allows the chute to act as the bearing. Fig. 25 illustrates inlet locations for force feeding either leg of the elevator. Ensure approximately 50 mm of clearance between the elevator buckets and the exposed screw.

To avoid choking the system, maintain the capacity of the conveyors at least 10% lower than the elevator capacity. Use chutes or transitions prior to the feed hopper for additional surge protection.

Feed meal and ground stock into the down leg of the elevator; these materials flow less smoothly than grain. Vent the buckets so air can escape during filling. This simple action improves both bucket filling and leg capacity.

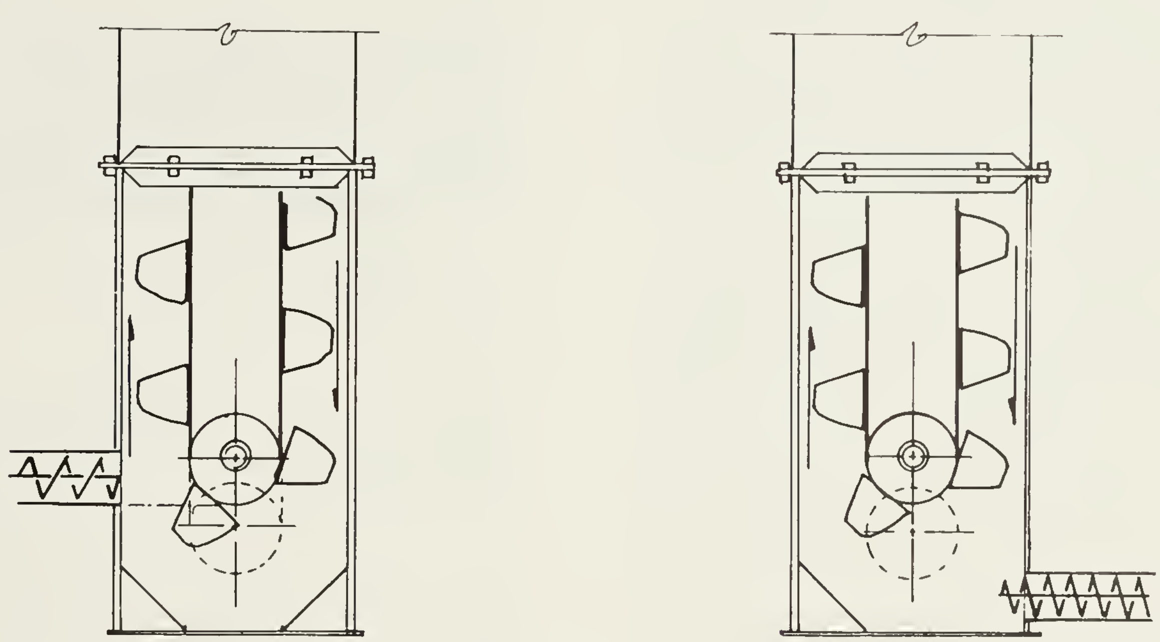


Fig. 25. Inlet positions for force-fed bucket elevators.

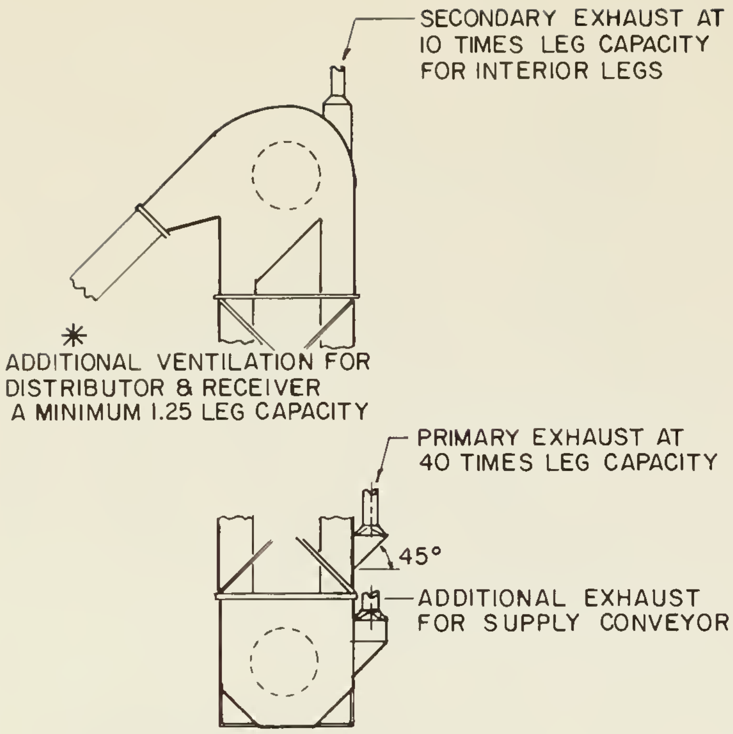


Fig. 26. Dust takeoff locations for bucket elevators.

Provide dust takeoffs above the loading level on the up leg (Fig. 26). A takeoff vent relieves any pressure induced by belt travel and assists in bucket filling. In addition, locate a second dust takeoff or pressure relief on the head section above the discharge spout.

4.9 Legging or trunking

The casing that encloses the belt and buckets is called legging or trunking. It provides a dust enclosure and structural support for the belt pulleys and accessories. Some elevators have single legging with a common enclosure for the up and down belts. More common in agricultural applications, however, is double trunking where separate leggings enclose the up and down belts. Properly braced, this configuration is structurally more rigid than a single leg.

Four factors determine the structural design of the legging: belt tension, elevator height, wind load, and accessories mounted on the elevator. Consult manufacturers' information on the casing thicknesses required.

Design the trunking to be dust and water tight, as well as structurally adequate for the service intended. Accurate alignment of the trunking ensures satisfactory elevator operation. Cross bracing, commonly installed during manufacture of the legs, provides rigidity between the dual legs. Jig fabrication assures the alignment required. During erection, shim joints between leg sections to maintain alignment.

Equip the legging with explosion doors designed to relieve excessive pressure, thus preventing damage to the casing. As well, provide access doors in each side of the up leg and on the outside of the down leg, above the boot, for belt and bucket inspection and maintenance.

4.10 Head and boot pulleys

Head and boot pulleys are usually fabricated steel drums with flange support from the centre shaft. Hubs and taper-lock bushings attach the flange to the shaft. In most cases the head shaft has two flanges, whereas boot pulleys, especially in smaller elevators, have a single flange located centrally.

Boot pulleys, commonly self cleaning, consist of a series of slats supported on a double-cone centre hub. This design significantly reduces dust build-up on both the hub and the back of the belt.

Align the head and boot pulleys accurately to prevent belt wander. Setting the belt tension too high or too low can cause it to slip or stretch. Any of these situations can lead to fire danger or decreased belt life.

4.11 Belting

Select the belt based on working tension and bucket projection, and modify the tension to accommodate belt splicing. Polyester or nylon cord belts with polyvinyl chloride (PVC) covers are quite common. The belting can be multi-ply fabric core or cord type core. In demanding applications, such as high lifts at high capacity, use steel cord belts. Add belt covers for resistance to fire, oil, and wear.

Expect belts made of conventional materials to stretch as much as 2–3.5% of their initial length before they stabilize. Newer belting materials, however, can reduce stretch to only 0.5%.

Mechanical or bolted splices usually serve as belt splices. Common splice types include bolted lap splices using cup bolts, butt joints using a bolted bar clamp, butt joints using alligator clamps, or laced joints. Consider these two factors when selecting belt splices:

- efficiency of the splice
- installation time

5 GUIDELINES FOR ERECTING CONVEYORS

Several factors govern the method of erecting bucket elevators: the elevator height, means of support, and location (i.e. whether indoors or outdoors). In any case, though, provide the

legging with lateral bracing during erection, and erect it straight and plumb. As well, use a gasket or seal the flange connections.

Choose from these three methods of erecting bucket elevators.

In the first method, hoist and erect individual sections of the elevator. However, this method requires working platforms supported from an adjacent structure for the full height. Erection can be slow and labor intensive.

Alternatively, partially assemble trunking in 7–10-m sections on the ground. Then use a crane to hoist the sections for erection.

The third option involves assembling the entire trunking and head on the ground. Then erect the leg with one crane lift. This method requires skill and care to prevent deformation or damage to the leg during erection.

Whatever the method of erection, the elevator needs foundations and lateral supports during all stages of construction.

5.1 Foundations

Base the design of the foundations on the dead and live loads for the elevator. Additionally, if using a tower, the foundation must resist overturning caused by wind load. Calculate wind loads according to the *National Building Code* for the region in which the elevator is being constructed. The foundation should also resist settling or shifting caused by frost penetration.

Generally, a structural slab on grade can serve as a foundation, depending on the soil conditions. However, piling may be more economical for large elevators or high towers.

5.2 Lateral support

Lateral support ensures the elevator can resist wind loads. Free-standing towers, either specially designed or purchased from suppliers, often serve as support. Elevators can also be braced to adjacent structures using structural ties placed at intervals of 7–10 m.

Guying commonly provides lateral stability when no tower or adjacent structures are available. Attach cables to the elevator trunking intervals of 7–10 m. Run these cables in four directions from the elevator and anchor them to posts set in the ground at grade level. Ideally, place the guy wires 90° from each other at a slope of 50° or less from horizontal.

The anchors, or deadmen, can be massive concrete blocks or poles made of steel, timber, or cast-in-place concrete. If choosing concrete blocks, bury them with the top surface flush with grade. If using poles, leave a portion of their length extended above grade, allowing the guys to be raised. This arrangement protects the poles from damage by mobile equipment.

Design the anchors to resist the horizontal and vertical forces transmitted by the guy wires. Solid concrete block anchors depend on mass and passive soil resistance for their stability. Pole anchors depend on skin friction between the earth and the poles to resist uplift. As well, passive soil pressure helps poles resist horizontal forces. Pole anchors must also withstand the guy wire forces and the bending moment of the cantilever extending above grade.

Use skin friction of the pole to establish how deep it must be set in the earth to offset the vertical component of the cable load. The horizontal component must be transferred in bending by the pole to the ground.

Mid-West Plan Service uses this calculation to determine pole depth:

$$s = \frac{1.47(P + wh) + (2.16(P + wh)^2 + 10.52ptM)^{0.5}}{2pt}$$

where s = pole imbedment depth (m)

P = horizontal force (N)

h = height above the ground (m)

p = passive soil pressure (N/m^2)

w = a uniformly distributed lateral load on the column which does not apply in this case

t = width of the pole (m)

M = bending moment (N·m)

The maximum bending moment occurs at a point equivalent to one-third the pole depth below the surface of the ground. Thus

$$M = P(h + s/3)$$

Calculate the pole imbedment depth by iterative approximations of these two equations.

Wooden or steel poles supply good lateral support but cast-in-place concrete is most suitable for several reasons.

Firstly, the large diameter of the embedded section provides more adequate load distribution to the surrounding soil than do other types of piles.

Secondly, the effective width of the concrete pole equals the diameter of the hole drilled. Therefore assumptions do not have to be made

regarding the internal friction angle of the backfill and its ability to spread the load over a width greater than the pole.

Thirdly, concrete poles provide much greater bending strength than do wooden poles. Sectional stability is not a concern.

Finally, the mass and physical size of a concrete pole makes it more noticeable and less subject to damage from vehicular traffic.

As with loading conditions on any section of the poles, designs must allow for combined axial and bending forces.

$$\frac{F_p / A}{S_t} + \frac{M / s}{S_b} \leq 1.0$$

where F_p = vertical pull-out force (N)

A = cross sectional area of post (m^2)

S_t = tensile strength (N/m^2)

M = bending moment (N·m)

s = section modulus (m^3)

S_b = bending strength (N/m^2)

Select the cable based on working load. Specify prestretched cable and provide a turnbuckle on each guy to allow for tension adjustment. Because temperature changes affect guy tension, check it at least twice a year. In summer, elongation of the guys may allow excessive lateral deflection. In winter, contraction of the guys can increase tension, possibly crippling the elevator casing.

Attach guy wires to the deadmen with rings and clevises, or with shackles. Use galvanized guy wires to resist corrosion. The high cost of stainless steel guy wires generally prohibits their use.

5.3 Distributors

In most applications, materials must discharge from the bucket elevator to several locations. Use diverter valves and distributors to accomplish this task, reserving valves for situations where material is directed to only two or three locations.

Frequently, single elevators handle several different materials, directing them to various locations. In these cases, distributors guide the materials to the appropriate unloading points.

The distributor uses a movable spout to direct material to various attached distribution spouts. Two main types of distributors are in wide use: the swing spout and the rotary distributor. Both types provide a total enclosure for the internal spouting yet allows for dust venting.

In the swing-spout distributor (Fig. 27) the feed spout swings on an arc in a vertical plane. The feed spout aligns with the selected discharge spout and directs the material as required. Feed handling systems commonly use swing spouts because of the steep angle of inclination possible with the directional control spout.

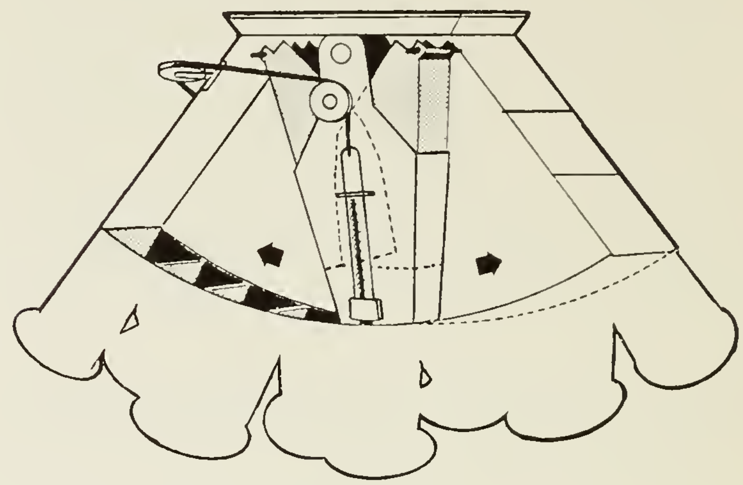


Fig. 27. Swing-spout distributor.

With the rotary-spout distributor (Fig. 28), material enters an offset spout which rotates on a vertical axis and aligns with discharge spouts, as selected. The slope of the internal spout ranges from 45–65° in five-degree increments. The distributor height increases with increasing spout slope.

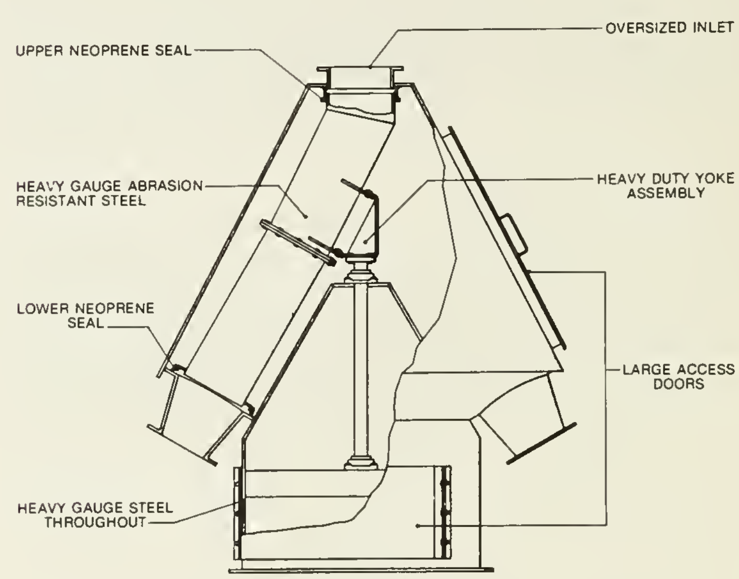


Fig. 28. Rotary-spout distributor.

Both types of distributors can operate either manually through a crank and cable arrangement, or by an electrical gear reducer In the powered models, operator commands

control the spout positions as directed by internal limit switches.

A wide range of distributor capacities is available. Select the appropriate size based on the size of inlet spouting. Consult manufacturers' information for additional selection criteria.

Match spouting and distributor connection sizes to avoid field erection problems or the need for costly transitions.

As well, ensure the internal and discharge spouts align. Distributors can cause cross contamination of material if the spouts are mismatched. Critical applications, such as feed handling and seed plants, require distributors that incorporate positive spout-to-discharge seals. These distributors provide either a spring-loaded collar at the connection, or are designed so the distributor spout drops into the discharge spout.

For proper operation and maintenance, distributors also require:

- access hatches
- pressure relief ports
- vent connections
- gasketted or caulked flanges

Three factors, in particular, influence selection of the distributor: the characteristics of the material to be handled, the initial velocity of the material entering the distributor, and the head room available.

When choosing a distributor for a planned facility, allow for more discharge ports than actually required so future expansion of the facility is possible.

5.4 Belting

A single carcass synthetic belt with rubber or polyvinyl chloride (PVC) covers generally make up modern belting. The multiple-fabric belting of the past is becoming rare in the agricultural industry. The belts available today provide improved strength, flexibility, and lower costs. Select belts for structural strength and electrical conductivity, as well as for resistance to oil, fire, and moisture. Manufacturers' literature supplies the working strength and characteristics of belt carcass and covers.

The following series of equations illustrate the mathematical method for determining belt operating tension.

First calculate the effective tension:

$$T_e = \frac{P_e \times 1000}{V}$$

where $T_e =$ effective tension (N)

$P_e =$ power (kW)

$V =$ velocity (m/s)

A second equation for effective tension:

$$T_e = T_1 - T_2$$

where $T_1 =$ tight side tension (N)

$T_2 =$ slack side tension (N)

Then determine tight side tension:

$$T_1 = T_e \times K_e$$

where $T_e =$ 1.5 lagged pulley, gravity takeup

$K_e =$ 1.8 lagged pulley, screw takeup

Having calculated T_1, then the slack side tension (T_2) becomes:

$$T_2 = T_1 - T_e$$

5.5 Buckets

Bucket materials include PVC, polyethylene, urethane, and cast metal, as well as mild, stainless, galvanized, and painted steel. The costs and life expectancy of the various bucket materials vary greatly.

In many applications, plastic buckets outlast steel buckets. As well, plastic buckets do not spark and so reduce the possibility of explosion. They also do not permanently deform as readily as metal buckets. For some applications, metal buckets coated with Teflon, PVC, or silicone are available. These especially are useful for handling sticky products.

Manufacturers offer various configurations and designs of elevator buckets.

5.6 Spouting

Use spouts (or chutes) to contain the material as it flows, by gravity, to a lower elevation. Maintain the flow rate between 0.3–0.45 m^3/h for each square centimeter of spout cross sectional area. However, use this range with discretion since slope, material flow characteristics, initial material velocity, and spout transitions affect the ultimate flow rate attained. Keep this 'rule of thumb' in mind: when unsure, make it steep.

Table 8 lists some typical spout slopes for a few conditions.

The material characteristics can significantly affect flow rate. For example, sunflowers easily flow through spouting at a slope of 45° for the first short while. However, the sticky coating they leave on the inside of the spout eventually blocks the flow at this slope. (Following the sunflowers with cereals or peas cleans the spout, by the way.) The rubbing action or friction the materials handled can also influence their movement through spouting.

In designing spouting systems, use round spouts because they require less steel than do square ones. Choose mild steel, ASTM A36 or firebox quality for spouts. Design the connections to permit periodic rotation of the spouting. This arrangement distributes wear evenly.

Try to avoid abrasion-resistance (AR) steels for agricultural applications. They are difficult to weld and expensive. For highly abrasive farm materials, use spouting with a square cross section and install abrasion-resistant liners made of AR steel, plastic, or ceramic.

5.7 *Spouting support* Within limits, spouting can be self supporting, provided it can resist gravity loading from the spouts and the weight of the material, and horizontal wind loading. Select spout wall thickness based on normal beam theory as applied to thin walls. Make allowance for wear that reduces wall thickness over time.

When the span exceeds the limits for self support, provide either intermediate supports or truss the spouting. Base the truss design on standard engineering principles. The spout takes the compression forces and the truss cables take the tension.

Table 8 Typical spout slopes

Product	Liner material	Typical slope
Dry grain	steel	40°
	low-friction liners	37°
	rubber	40°
	urethane	40°
	ceramic	45°
Wet grain	steel	50°
Soft and ground stock		50°
Dusts		60°

Source: *Grain spouting design and maintenance.*

Use three or four tension cables made of galvanized prestretched steel with a turnbuckle on each to adjust tension. Attach the cable to the spout ends and separate it from the interior points by spreaders or spiders. Be sure to protect the cables from abrasion where they pass over the spider arms, because the critical loads occur at these points. As well, weld strengthening collars to the spout to prevent it buckling.

Install spouting with slip joints at connections to equipment such as distributors, valves, and bins (Fig. 29). This configuration compensates for shifting that may occur with temperature changes or with differential settling.

Keep the travel velocity of material in the spout below 8.7 m/s. Reduce the travel velocity with flow retarders and dead ends or adjust the spout slope and length (see Table 9). This design limits the wear on both the spout and the discharge elbows (Fig. 30).

5.8 Bucket elevator safety

Do not open access and inspection doors while the equipment is operating and keep drive guards in place. Equip all feed and discharge openings with grating guards.

Fire and explosion, however, pose the greatest dangers to bucket elevator operations. A variety of common safety devices and monitors can protect against disaster:

- under-speed indicators, mounted on the boot shaft or the back of the upside trunk
- plugged-chute indicators, mounted at either the elevator discharge or the distributor inlet
- backstops, to prevent the backward motion of the loaded belt in an emergency shutdown. These devices ensure the material in the buckets does not discharge into the boot. They also simplify restarts.
- hot-bearing indicators, installed at the head and tail shafts
- ammeters, mounted on the leg drives to monitor the power draw of the motor. They allow the operator to set the feed rate to prevent overloading.

Avoid these dangerous operating practices:

- failure to close the hatches after service and inspection. Fingers accidentally inserted into a hatch may be amputated by the cups traveling at 2–3 m/s in the trunking.
- failure to provide a grill or grating ahead of the feed point into the bucket elevator. Sticks, boards, or pieces of reinforcing steel may enter the elevator.

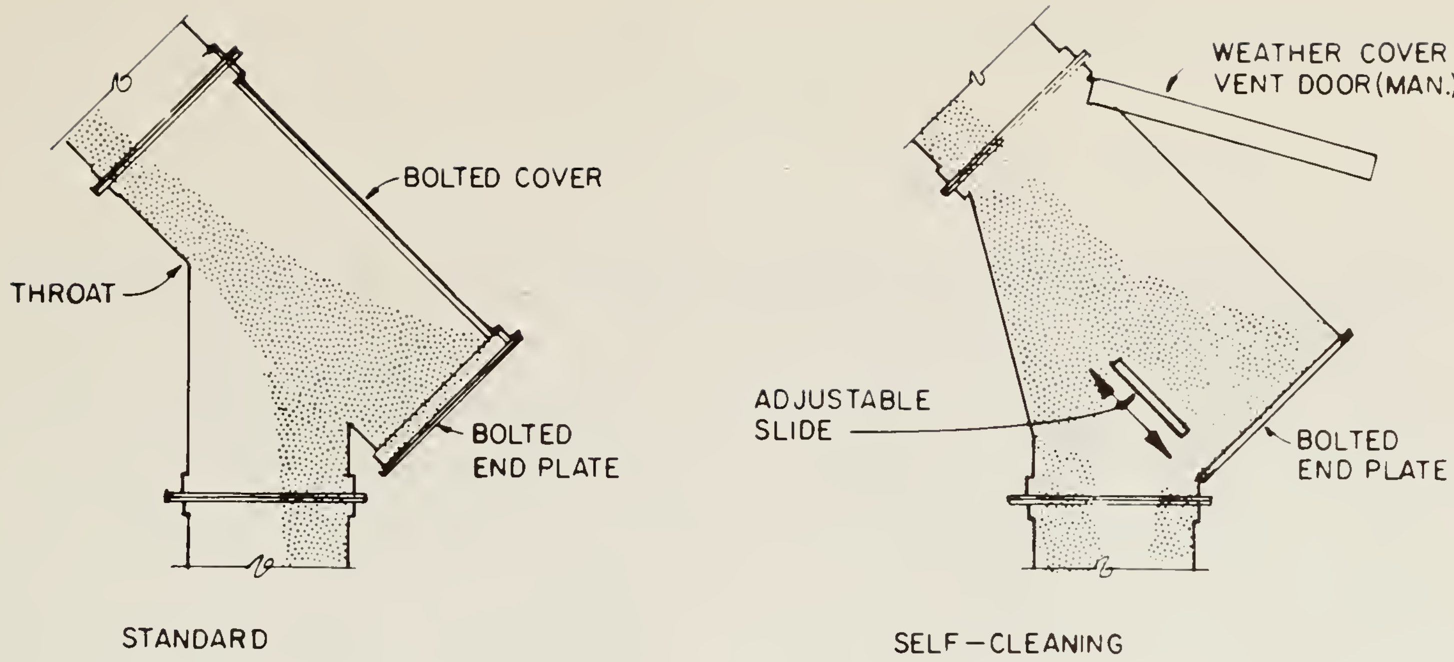


Fig. 29. Standard and self-cleaning dead-ends.

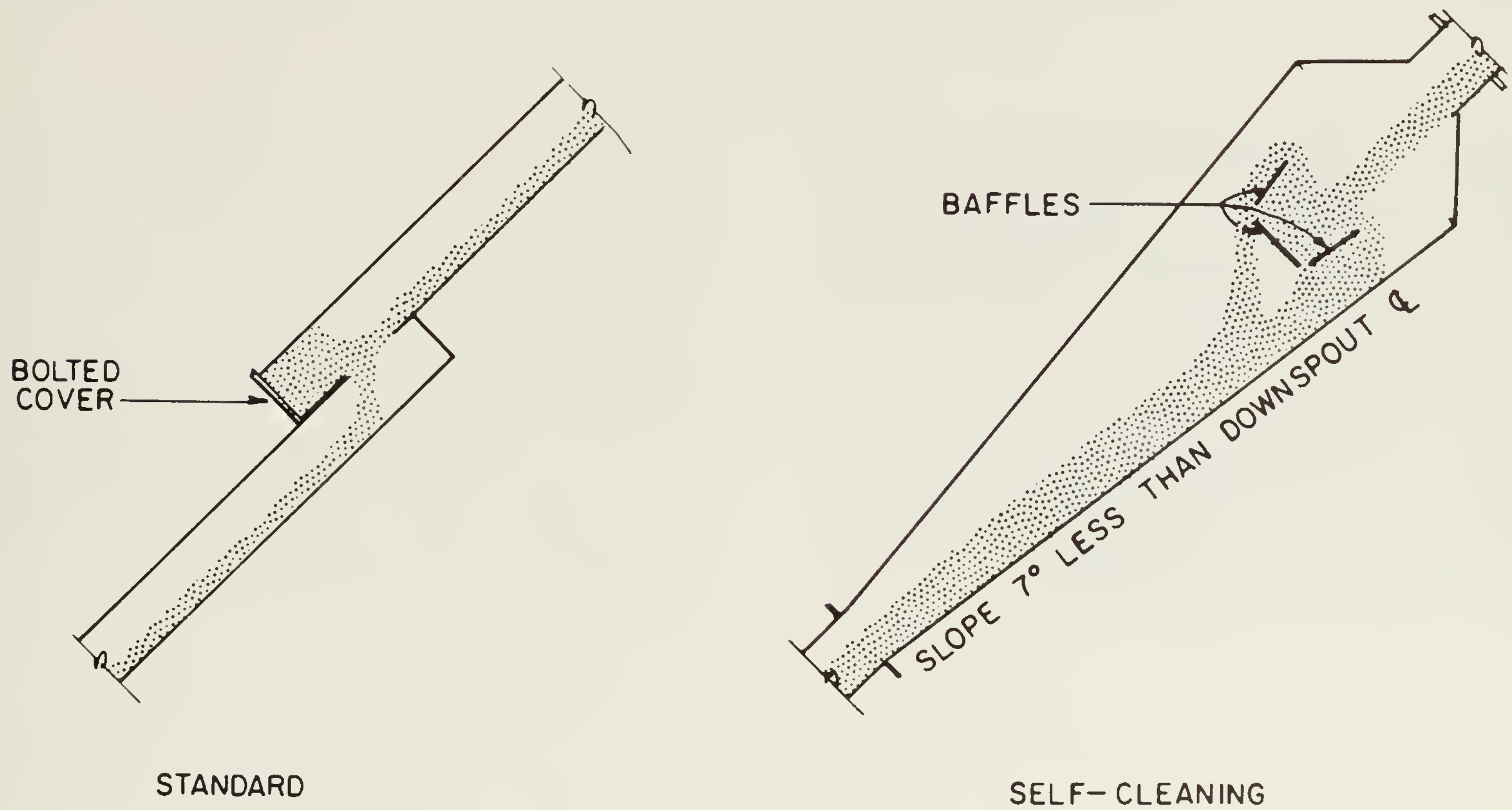


Fig. 30. Standard and self-cleaning flow retarders.

- failure to maintain accurate belt alignment. A misaligned belt wears prematurely and increases the power required for operation. The resulting abrasion between the trunking and the belting or cups can raise temperatures high enough to start a fire or promote sparks which may initiate an explosion.

5.9 Material damage control

The head sections of contemporary bucket elevators generally provide acceptable discharge of material. In some instances, though, material does impinge on the head section and fractures. Fractured seed grain germinates poorly. Corn, peas, and beans are particularly susceptible.

Several design features can limit impingement of grain on the head. Set the head bonnet height from the centre line of the head shaft to the underside of the bonnet equal to the head pulley diameter plus 1.5 times the bucket projection In addition, match the shape of the discharge path to the grain trajectory, as closely as possible.

Table 9 Spout slope (°) and length (m) vs. grain speed (m/s)

Spout length (m)	Spout slope 35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Grain speed (m/s)											
1.5	2.0	2.7	3.15	3.6	3.9	4.2	4.5	4.8	5.0	5.1	5.3	5.5
3.0	2.9	3.8	4.4	5.0	5.6	6.0	6.4	6.7	7.0	7.3	7.5	7.7
4.6	3.6	4.6	5.5	6.2	6.7	7.3	7.7	8.2	8.6	8.9	9.2	9.5
6.1	4.1	5.3	6.3	7.1	7.7	8.5	9.0	9.5	9.9	10.3	10.7	
7.6	4.6	6.0	7.0	7.9	8.8	9.5	10.0	10.6				
9.1	5.0	6.5	7.7	8.7	9.6	10.4	11.0					
12.2	5.8	7.5	8.9	10.0	11.1							
15.2	6.5	8.4	9.9	11.2								
18.3	7.1	9.2	10.9									
21.3	7.6	10.0										
24.4	8.2	10.6										
27.5	8.7											

Keep the head pulley speed to within 5% of the optimum. If the speed is too high, grain or feed stock bounces off the head casing and falls back down the trunking. Insufficient speed results in improper cup discharge. Both situations increase power demand and add to product degradation.

Expect some damage in the boot due to impact of the cups on the kernels. However, less brittle synthetic cups may reduce the impact force. And although damage is not directly related to belt speed, increased damage results from speeds in excess of 2.5 m/s.

Most of the damage attributed to bucket elevators actually occurs after the material leaves the elevator. Abrasion in the spouts and, particularly, the impact of the grain dropping into bins causes more damage than the action of the elevator itself. Reducing the drop height significantly lessens grain damage. Maintain the drop into storage less than 12 m, if possible. Damage increases dramatically as the drop exceeds 20 m. Some users claim pea or corn ladders reduce impact damage on these materials; however, the benefits of using ladders have not been quantified.

REFERENCES

Agler, L.C. 1985. *Grain spouting design and maintenance.* GEAPS Annual International Technical Conference.

Boumans, G. 1985. *Grain handling and storage.* Amsterdam: Elsevier, C72637100.

Ditzenberger, D. 1974. *Methods of reducing grain damage in handling.* GEAPS Annual International Technical Conference.

Handbook of conveyor and elevator belting. Akron: The Goodyear Tire and Rubber Company, 1982.

Larson, F.D. 1978. *Conveying.* Canadian Feed Industry Association.

Professional design supplement to the MWPS structures and environment handbook. Ames: Midwest Plan Service, 1978.

Protz, A. 1976. *Farm feed processing and handling.* Agri. Can. Publ. 1572.

Screw conveyor engineering catalogue no. 7700. Sullivan Strong Scott, 1976.

Syntron and link-belt material handling equipment. Homer City: FMC Corporation Material Handling Equipment Division, 1983.

Technical manual, bulk materials handling. Middletown: Fenner America Ltd., 1980.

DUE DATE

201-6503

Printed in USA